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TECHNICAL REPORT SERIES

SMALL HYDRO PROGRAM FEASIBILITY REPORTS

February 1982
Division of Water Resources
Office of Natural Resources
Tennessee Valley Authority

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ORIGINAL

TVA/ONR/WR-82/11

SMALL HYDRO PROGRAM

FEASIBILITY REPORTS

Prepared by

Hydropower Planning Section

WSDB Report No. WR28-1-510-133

Water Systems Development Branch

Division of Water Resources

Office of Natural Resources

February 1982

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Small Hydro Program - Feasibility Reports

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Summary

Summary

The growing national concern over the cost and availability of future energy supplies has generated a renewed interest in hydroelectric power. This is for good reason since hydroelectric power is a readily available energy source which uses a renewable fuel. It is a proven technology and existing installations provide the most efficient, inexpensive, and reliable source of electricity available today.

Since the beginning of the National Hydropower Study, initiated by the U.S. Corps of Engineers in 1976, we have witnessed a renewed awareness and interest in small hydro, not only by the utility industry but also by the general public. To investigate the small hydro potential of restoring or adding power generating facilities at existing non-Federal dams in the Tennessee Valley Region, an engineering study was initiated by the Water Systems Development Branch of the Office of Natural Resources at the instruction of the TVA Board of Directors.

The first phase of the study, which was completed in June 1980, consisted of an inventory and screening of the existing dams to eliminate those dams that were obviously unsuitable for further consideration. Reconnaissance level cost studies were made for a number of dams having the best possibilities for redevelopment (see Appendix A).

This document is a compilation of more detailed feasibility reports completed in the second phase of the investigation. These studies encompass eight of the most promising sites selected from the reconnaissance phase. TVA does not at this time propose to undertake restoration of these facilities. However, this report provides details concerning equipment and construction necessary to put the facilities into operation and suggests options that exist for each site.

Following is a brief summary of the results from the feasibility studies completed for eight dams.

Site	County and State	Installed Capacity (kW)	Average Annual Energy (MWh)	Cost ($/kW)	B/C Ratio Economic Forecast Low[1]	B/C Ratio Economic Forecast High[2]
Burgess Falls Dam	Putnam, TN	370	1,300	2,570	0.76	1.14
DeSoto State Park Dam	DeKalb, AL	700	2,000	2,200	0.44	0.60
Eve Mills Dam	Monroe, TN	33	100	3,300	0.28	0.38
McMinnville Dam	Warren, TN	225	1,400	4,000	0.78	1.18
Old Columbia Dam	Maury, TN	730	3,200	3,030	0.81	1.23
Shelbyville Dam	Bedford, TN	230	1,300	3,900	0.80	1.20
Shoal Creek No. 1 Dam	Lawrence, TN	300	1,100	3,900	0.53	0.82
Sparta Dam	White, TN	300	1,400	2,100	0.73	0.99

The costs used in this report reflect construction costs based on TVA's experience on similar work at larger projects including overheads normally used in TVA accounting procedures, which may not be applicable to all developers. Also, the economics of these sites can be more favorable if a developer has the ability to reduce costs, to secure low interest financing, or can take advantage of tax benefits available to small hydro investors.

It is recommended that a detailed financial analysis be performed by the potential developer before a decision is made whether or not to proceed with redevelopment of a site.

[1]For the low economic forecast power benefits and operation and maintenance costs are assumed to escalate 7.3 percent for the first 11 years, 5.5 percent for the next 8 years, and 6.0 percent for the last 16 years of the 35-year service life.

[2]For the high economic forecast power benefits and operation and maintenance costs are assumed to escalate 10.5 percent for the first 11 years and 10.0 percent for the remainder of the 35-year service life.

APPENDIX A

SMALL HYDRO SITES

Appendix A

Small Hydro Sites for Which Reconnaissance

Level Studies were Prepared

Site Name	State	County	Stream
Burgess Falls Dam	TN	Putnam	Falling Water River
David Crockett Dam	TN	Lawrence	Crawfish Creek
DeSoto State Park Dam	AL	Dekalb	West Fork Little River
Eve Mills Dam	TN	Monroe	Fork Creek
Evins Old Mill Dam	TN	Dekalb	Fall Creek
Gate City Dam	VA	Scott	Big Moccasin Creek
Harms Dam	TN	Lincoln	Elk River
Hungry Mother Dam	VA	Smyth	Hungry Mother Creek
Hyder Dam	TN	Carter	Buffalo Creek
Ivy Dam	NC	Madison	Ivy River
Ketner Mill Dam	TN	Marion	Sequatchie River
Lake Malone Dam	KY	Muhlenberg	Rocky Creek
Laurel Hill Dam	TN	Lawrence	Peter Cave Creek
McMinnville Dam	TN	Warren	Barren Fork River
Old Columbia Dam	TN	Maury	Duck River
Peery Mill Dam	TN	Blount	Little River
Sharps Mill Dam	AL	Lauderdale	Little Cypress Creek
Shelbyville Dam	TN	Bedford	Duck River
Shoal Creek No. 1 Dam	TN	Lawrence	Shoal Creek
Sparta Dam	TN	White	Calfkiller River
Townsend Light Dam	TN	Blount	Little River
Walker Mill Dam	TN	Sevier	West Prong Little Pigeon River
Walterhill Dam	TN	Rutherford	East Fork Stones River
Western Carolina University Dam	NC	Jackson	Tuckasegee River

APPENDIX B

BURGESS FALLS DAM

APPENDIX B

FEASIBILITY REPORT - BURGESS FALLS DAM

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SUMMARY OF PRINCIPAL FEATURES

Burgess Falls Dam

Location	
On the Falling Water River in Putnam County, Tennessee	
Owner	
City of Cookeville, Tennessee	
Streamflow	
Drainage area	124 sq. miles
Average discharge	200 cfs
Tailwater	
Normal operating	El. 850.7
Minimum	El. 850.4
Operating Heads (net)	
Maximum	31.8 ft
Minimum	29.2 ft
Rated	30.2 ft
Dam	
Type	concrete gravity
Length	369 ft
Height	40 ft
Top of spillway	El. 872.6
Top of spillway gate	El. 882.6
Possible Power Facilities	
Type	prefabricated hydroelectric generating station
Hydraulic turbines	
Number	one
Type	Francis, horizontal shaft
Rated output	552 hp
Runner diameter	1170 mm (46 in)
Generator	
Type	induction, horizontal shaft
Rating	370 kW
Water conductor	
Type	48-in steel penstock
Length	55 ft.
Plant output:	
Average annual energy	1,300,000 kWh
Cost	
Total project cost	$950,000
Cost per kW	$2,570

SUMMARY

This report presents the results of a study to determine the feasibility of restoring the hydroelectric generating facilities at Burgess Falls Dam. The costs used for this report reflect construction costs experienced by TVA including overheads normally used in TVA accounting procedures and may or may not apply to a developer.

The evaluation of several alternative plans using TVA costs and benefits and an assumed discount rate indicates that the redevelopment of Burgess Falls Dam could be economically feasible to a developer whose financial situation is suitable. A detailed financial analysis would be required by a developer for him to reach a final decision on project implementation.

I. INTRODUCTION

The purpose of this report is to investigate the possibility of restoring hydroelectric power generation facilities at the Burgess Falls Dam on the Falling Water River in Putnam County, Tennessee.

This report is part of the second phase of TVA's Small Hydro Program which was begun in 1979 to investigate the potential for small scale hydroelectric production in the Tennessee Valley Region. The first phase, which was completed in June 1980, consists of an inventory and screening of existing non-Federal dams in the Tennessee Valley and the TVA power service area. The second phase consists of more detailed feasibility studies on ten of the most promising sites based on the reconnaissance phase.

Included in the feasibility analysis for Burgess Falls Dam is a detailed cost estimate, evaluation of project benefits, and computation of a Benefit-Cost ratio. A potential developer can use these to help make a decision regarding whether or not to proceed with rehabilitation of the facility.

II. SITE HISTORY

The first dam built on the site of Burgess Falls Dam was the Cookeville Dam built by the City of Cookeville in 1922 for the purpose of generating electric power. The project used the dam to divert the flow of the Falling Water River through a flume to a powerhouse located below Burgess Falls.

The dam was 26 feet high and 310 feet long and consisted of a concrete gravity section and an earthfill section with a concrete core wall. The intake was located near the left abutment and directed the water into a 30-inch wood stave penstock. The penstock carried the water 2,631 feet downstream to the powerhouse, crossing the river twice on suspension bridges, and at one point tunneling through a bluff.

The powerhouse was an 18-ft x 20-ft concrete structure containing a turbine built by Wellman-Seaver-Morgan Company. A 19-inch bronze runner developed 650 hp under a head of 220 feet. The plant was rated at 360 kW.

This installation was operated until June 29, 1928, when a flood of 23,500 cfs washed out the earthen portion of the dam and the powerhouse. The dam was then rebuilt to its present configuration. The unit in the new powerhouse constructed downstream of the original powerhouse developed 1600 hp under a head of 230 feet and was operated until its retirement in 1944.

In 1973, the City of Cookeville entered into a contract with the State of Tennessee which conveyed to the State the land adjacent to the Burgess Falls project with the provision that it be developed according to the Natural Areas Preservation Act. The City still maintains ownership of the dam.

III. SITE DESCRIPTION

A. General

Burgess Falls Dam is located in Putnam County, Tennessee, on the Falling Water River (see Figures 1 and 2). The major features of the

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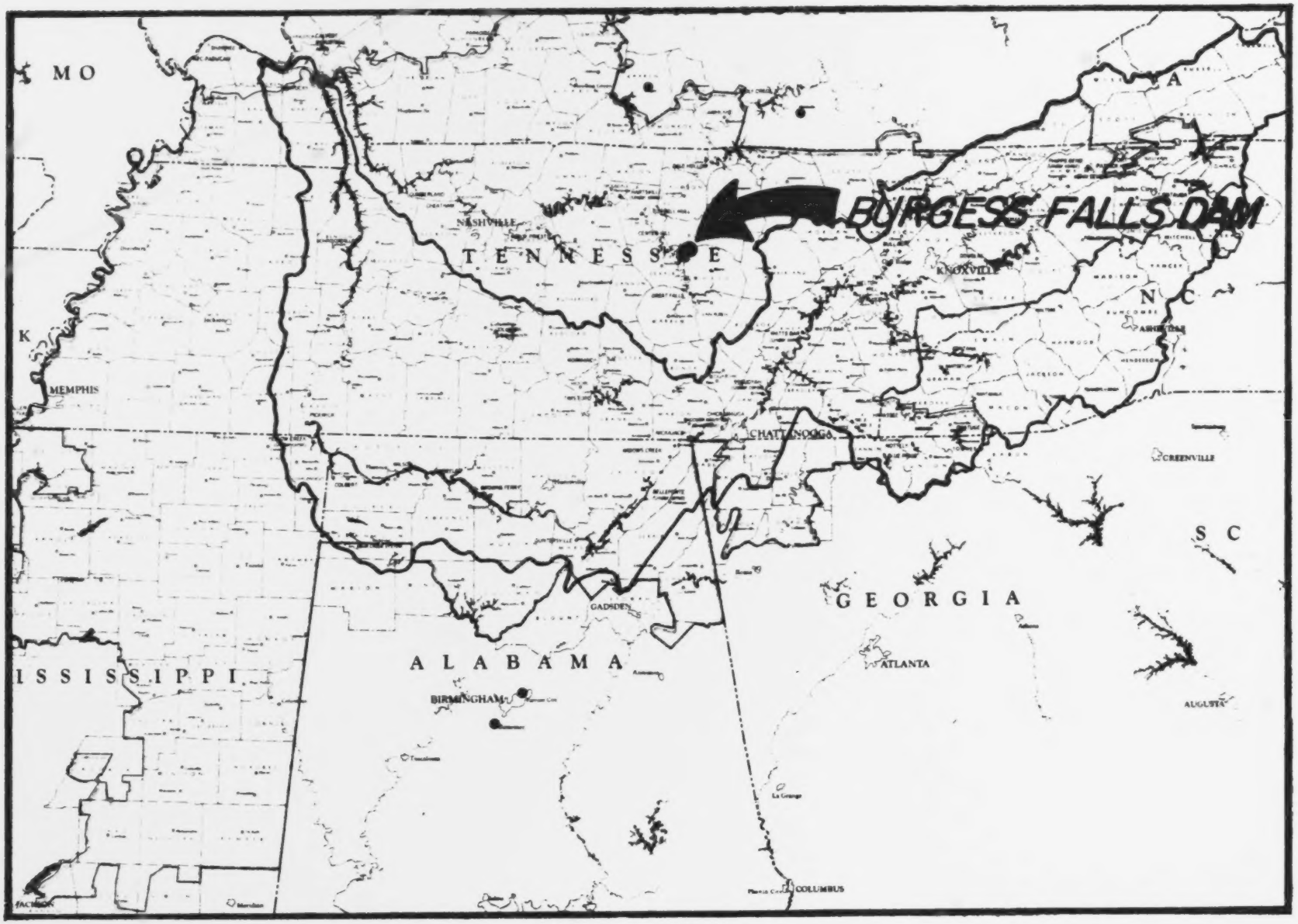

Figure 1. Location Map

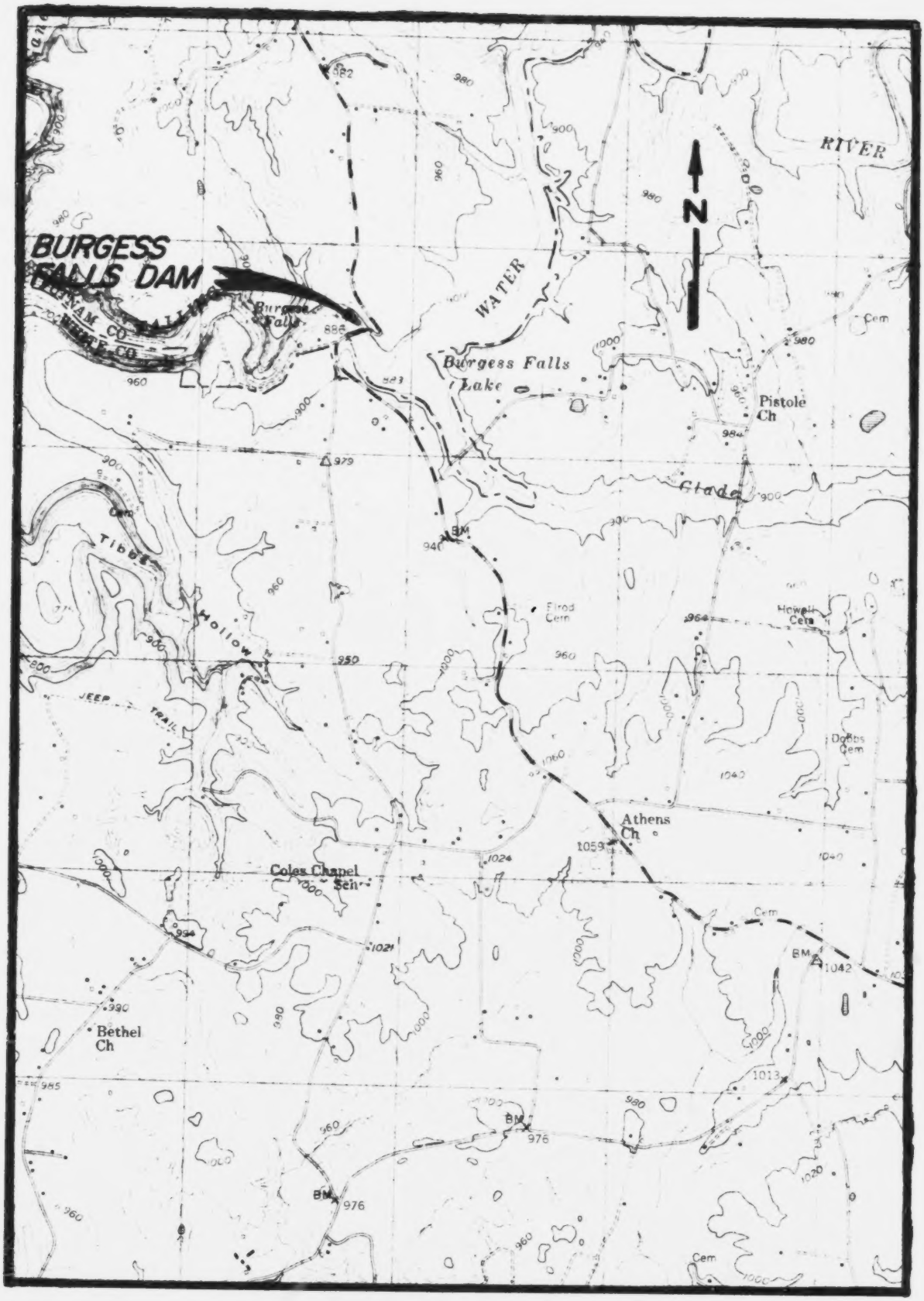

Figure 2. Vicinity Map

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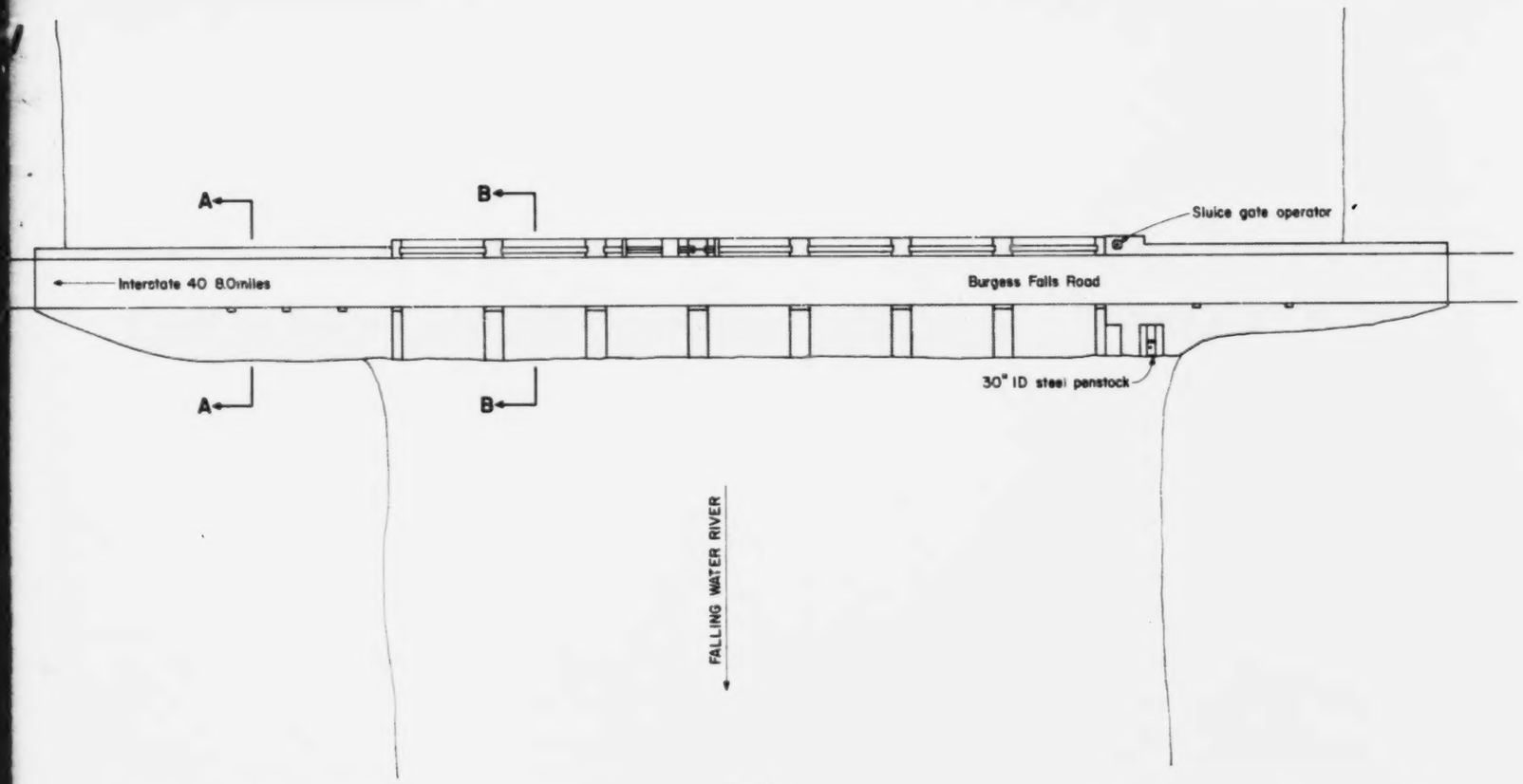

PLAN

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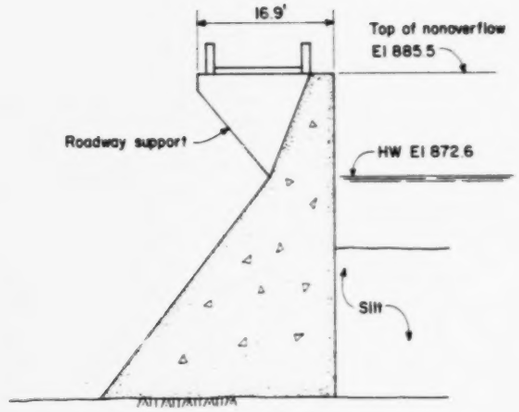

SECTION A-A

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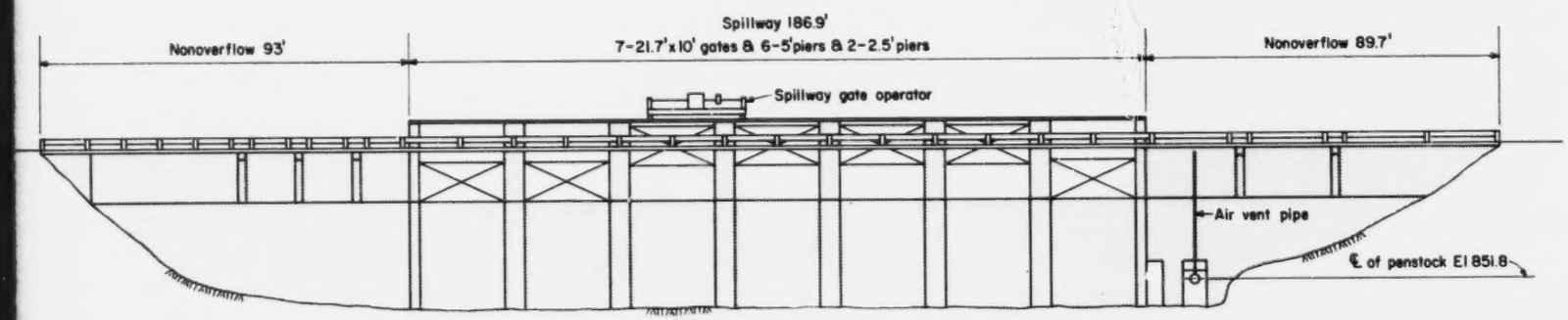

DOWNSTREAM ELEVATION

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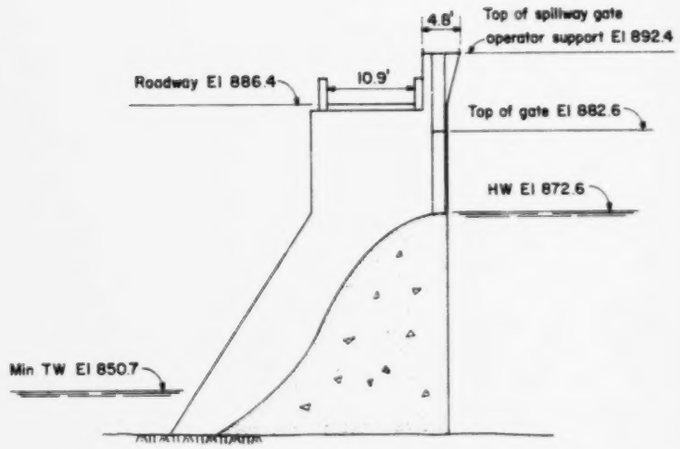

SECTION B-B

Scale 10 0 10 20 Feet

Figure 3. Existing Facilities-Burgess Falls Dam

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project consist of a dam with a roadway, remnants of a powerhouse and penstock supports (see Figure 3). Access to the dam is via the Burgess Falls Road which crosses over the dam.

Currently the site is part of a state of Tennessee nature area. A 115-foot water fall, the focal point of the nature area, is located approximately one mile downstream of the dam.

B. Dam

The dam is approximately 369 feet in length and 40 feet high. The reservoir is controlled by seven 22-foot x 10-foot spillway gates, four of which are presently secured in the open position. Some surface spalling and cracks can be seen along the pourlines of the ogee spillway and piers, and some leakage is visible through a 4-inch hole in the downstream side of the left nonoverflow section. The mobile spillway gate operator is rusty and not operative. There is a low level sluice and a 30-inch steel penstock located in the left nonoverflow section. At the time of our inspection, there was flow through the sluice, but the downstream penstock gate was closed and no flow was observed from the penstock. With the exception of the spillway gates and the roadway the dam appears to be in good condition.

C. Powerhouse

The powerhouse is a concrete structure in a deteriorated condition. It once housed a single unit, but only the generator floor and floor supports remain. The powerhouse is located approximately 650 feet downstream from Burgess Falls.

IV. HYDROLOGY AND HYDRAULICS

Land drained by the Falling Water River is mainly agricultural in use and totals 124 square miles at Burgess Falls Dam. A small reservoir with no appreciable storage capacity is impounded by the dam and is used primarily for recreation. Precipitation in the area averages 50 inches per year. Based on historical data from an upstream streamflow gage, the average flow at the dam is 200 cfs and the minimum flow is approximately 2 cfs. The maximum known flood occurred on June 29, 1928 and was computed to be 23,500 cfs.

A flow duration curve was generated using flow adjusted by relative drainage areas from a USGS streamflow gage on the Falling Water River near Cookeville. The drainage area at this gage is 67 square miles, and records are available from 1932 to 1956. Figure 4 is the adjusted duration of flow curve for Falling Water River at Burgess Falls Dam.

V. PROJECT DEVELOPMENT

In selecting the best redevelopment plan for the project, several alternative powerhouse sites were considered. The maximum power that could be developed at the site would be from a unit installed below the falls. Approximately 230 feet of head could be obtained at this location, but there are major problems associated with this site. These problems include difficult access, need for a long penstock, flooding of the site by the normal operation of Center Hill Reservoir, and environmental problems.

The area upstream and downstream of the falls is confined on both sides by sheer walled cliffs. Access to the powerhouse would require

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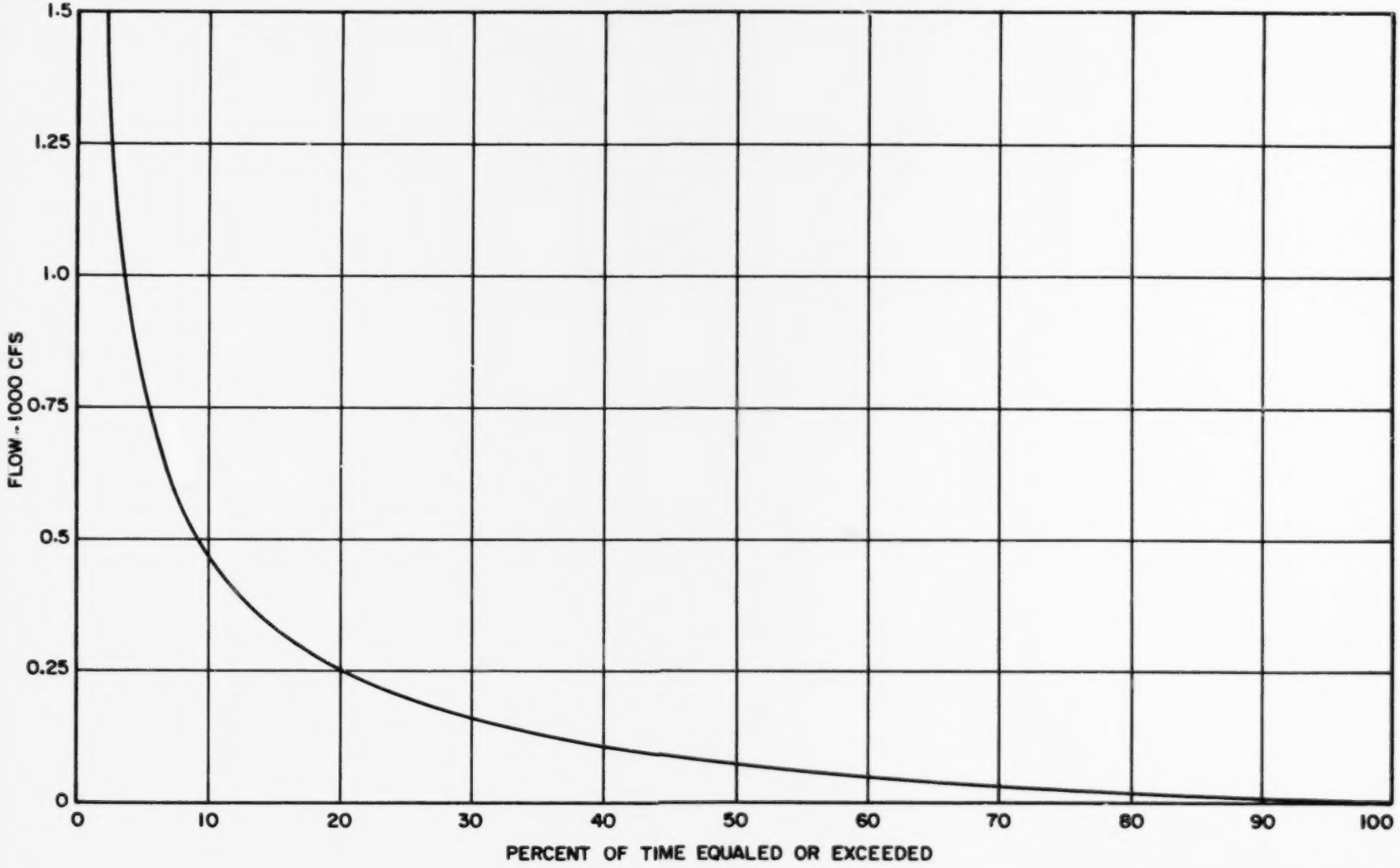

Figure 4. Duration of Flow

construction of an access road approximately three to four miles long that would originate downstream of the site. Four bridges would be required to cross arms of Center Hill Reservoir, and the road would be subject to flooding by the normal operation of Center Hill. Along with road construction costs, additional expense would be involved for easement on private and public lands.

Almost a mile of steel penstock would be required to carry water to the turbine; and, due to the difficult terrain, the penstock would require special supports and anchorages.

Because of the fluctuation of Center Hill Reservoir, the powerhouse would be subject to periodic flooding. Thus, the powerhouse would require some degree of waterproofing or the generator floor would have to be built above the maximum pool level of Center Hill Reservoir.

If the powerhouse were sited below the falls, the penstock would divert most of the flow of the river and would often dry up the falls. Since the falls is the focal point of the area, any continual reduction of flow over the falls would detract from the scenic area. In order to remedy this situation, the water could be released to the falls during daylight hours and used for power generation at night. However, this would reduce total plant output and the resulting revenue.

Due to the above problems, this site was eliminated from further consideration.

All powerhouse sites above Burgess Falls, except at the dam, are not acceptable because of extremely difficult and costly access and limited siting space for the powerhouse.

Another alternative considered was a powerhouse that would be added to the left nonoverflow section of the dam, using a vertical Francis

turbine connected to the existing penstock. This alternative was ruled out because of the large amount of civil work required to build the powerhouse.

The best alternative for Burgess Falls Dam appears to be a prefabricated Mini-Hydel hydroelectric station manufactured by Barber Hydraulic Turbine Ltd. and located immediately downstream of the dam. A 48-inch diameter steel penstock would replace the existing 30-inch penstock in order to carry the required flow. The seven spillway gates would be repaired and lowered to increase the available head by 10 feet. This installation, shown in Figures 5, 6, and 7, offers significant reduction of onsite construction costs, because the station is factory assembled and shipped as a unit to the site. Once onsite, it is erected on a simple concrete foundation, and turbine floor. The station utilizes a standardized horizontal Francis runner mounted on the turbine floor and all equipment is protected from flooding by a curved metal shell.

Three stations of different capacities were considered to optimize energy production. The unit selected would have a 1170 mm (46.0 in) diameter runner and would produce approximately 370 kW under a 30.2-foot net head.

Normal operation of the Mini-Hydel station would be unmanned and would feature manual startup and automatic shutdown. All necessary controls and instrumentation are contained in the station. The induction generator, which takes its frequency and voltage regulation from the power grid, eliminates many of the problems of interfacing a small generator with a large distribution system. A gate operator and constant head monitor would be installed to prevent drawing of the reservoir during periods of low flow. The cost estimate for developing Burgess Falls Dam

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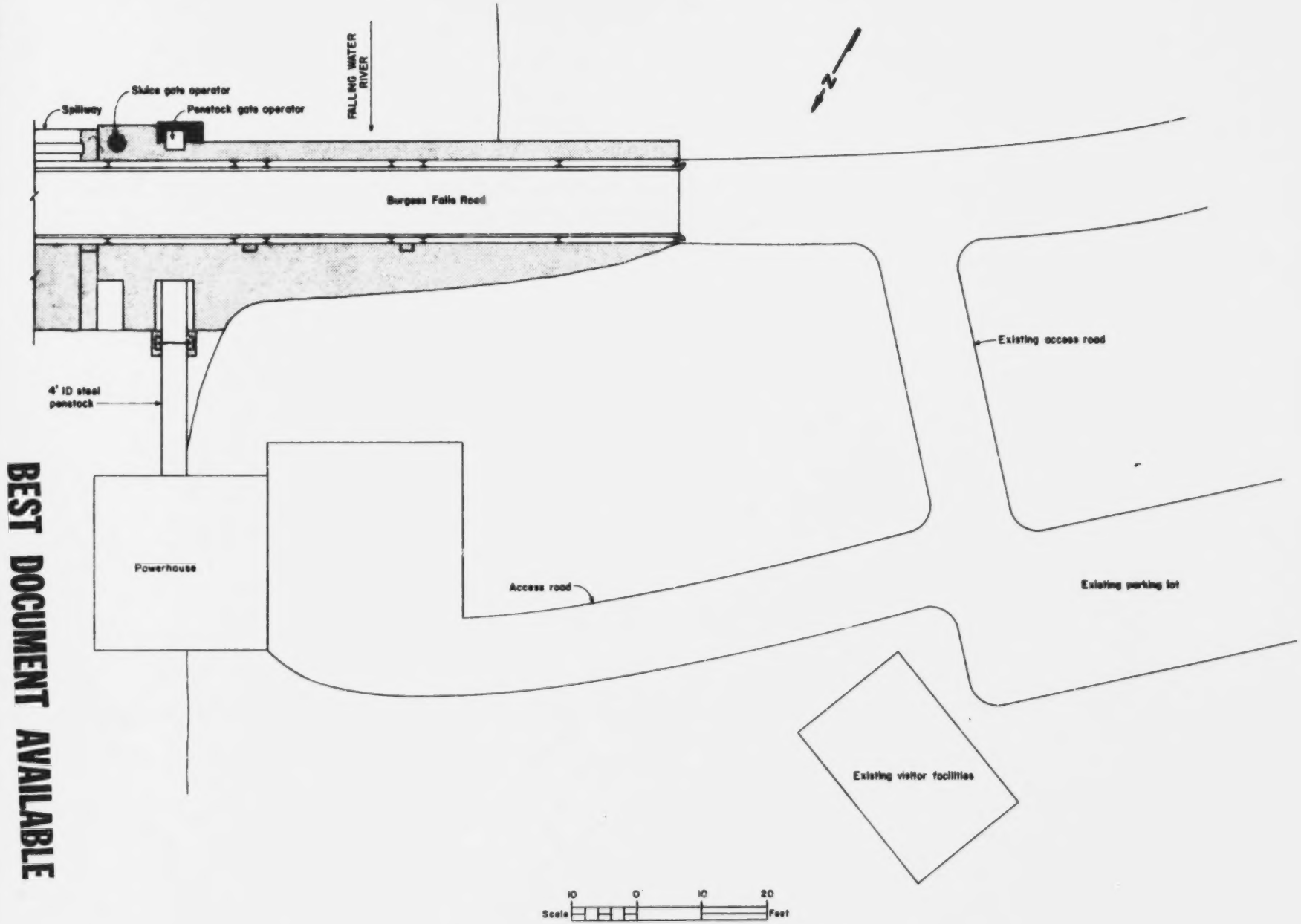

Figure 5. Possible Site Plan–Burgess Falls Dam

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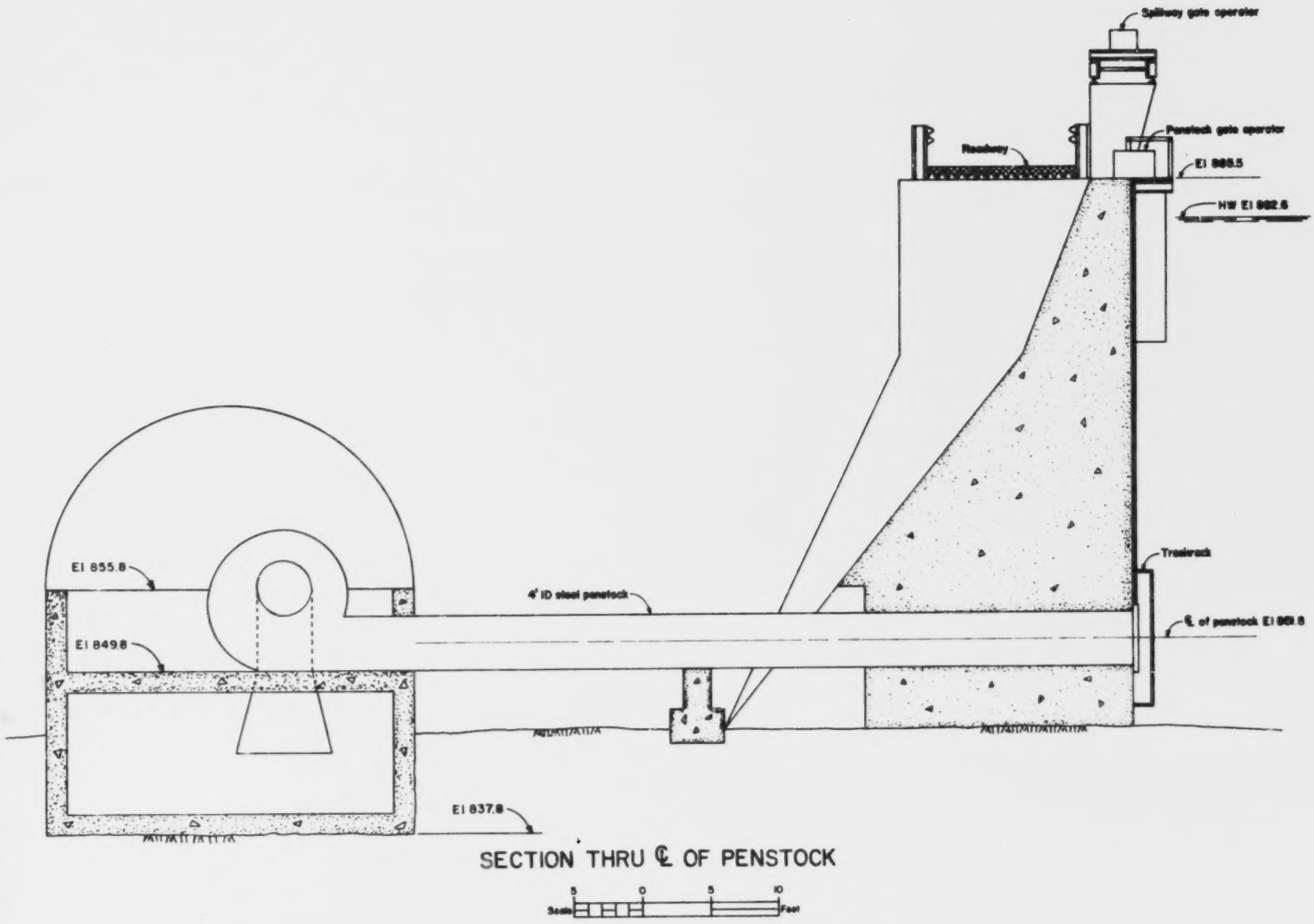

Figure 6. Possible Redevelopment Plan–Burgess Falls Dam

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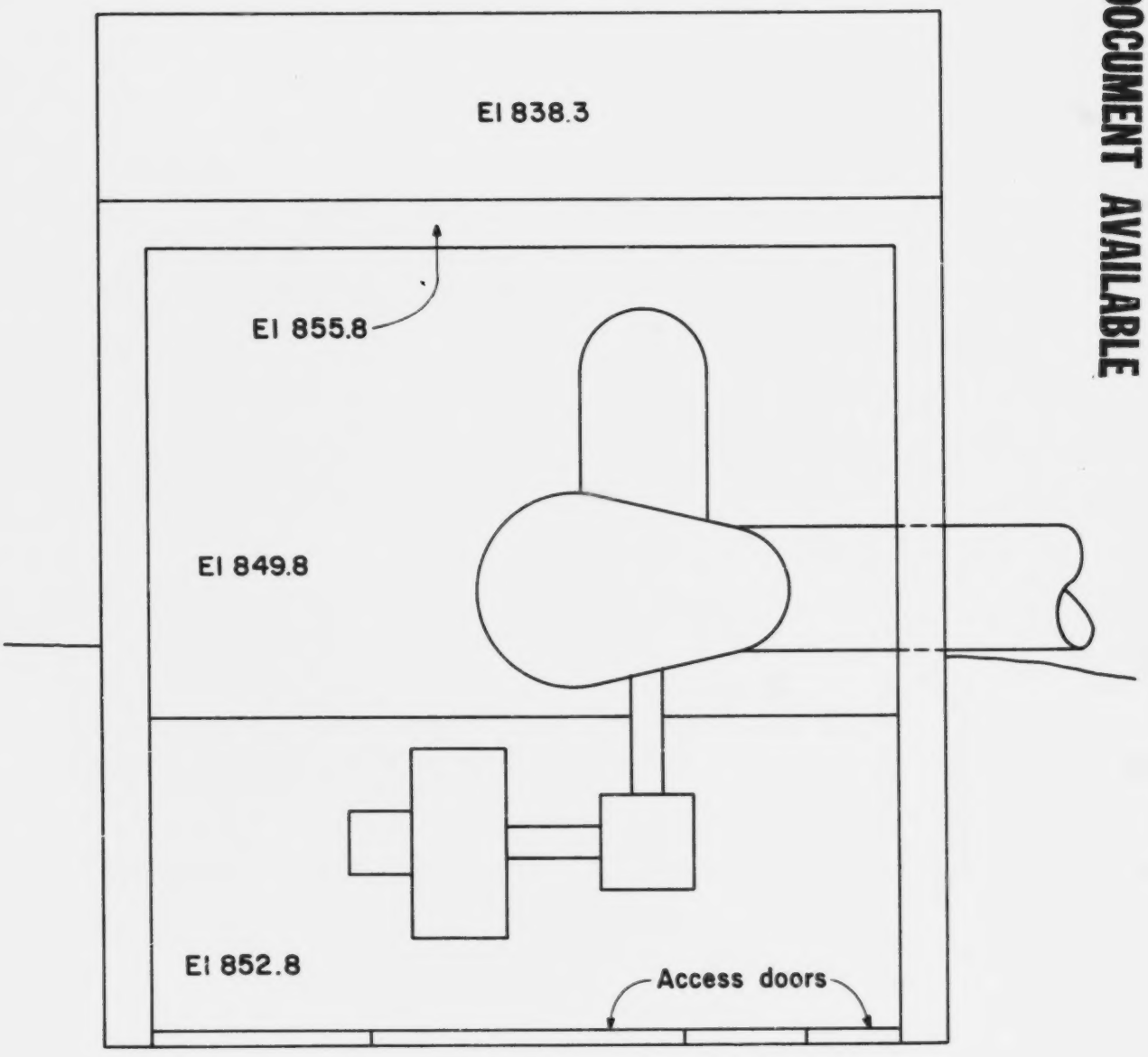

PLAN-GENERATOR FLOOR

SCALE: 1"=5'

Figure 7. Possible Redevelopment Plan-Burgess Falls Dam

utilizing the Mini-Hydel station is included under the section on project costs.

Other major construction items include:

1. Repairing spillway gates and replacing gate operator
2. Removing forebay silt
3. Replacing sluice gate and operator
4. Excavating tailrace
5. Replacing penstock
6. Placing Mini-Hydel substructural concrete

VI. POWER PRODUCTION

It is assumed that operation of the proposed hydroplant would be run-of-river. The potential power was determined utilizing the duration of flow curve shown in Figure 4. Usable flow under the curve was divided into several increments and average annual generation was computed by summing the potential energy from each increment under the curve. For this computation, a specific efficiency value was assigned to each increment of flow based on manufacturer's unit performance curves and net heads were computed using a tailwater curve and accounting for losses in the system.

Average annual energy produced by the Mini-Hydel station was estimated to be 1,300,000 kWh. At full gate (190 cfs) the unit is rated at 370 kW with an overall efficiency of 77 percent at 30.2 ft net head.

VII. PROJECT COSTS

The project cost in 1981 dollars of the most feasible redevelopment plan is $950,000 and is comprised of estimates of equipment and structural costs, interest during construction, contingencies, and overheads. The major items in the estimate are the prefabricated power plant, penstock, repair and alteration of the existing facilities, and site preparation. A summary of these costs is shown in Figure 8. The manufacturer provided the cost of the prefabricated station, and other costs are based on TVA's estimated costs. Operation and maintenance costs are assumed to be $10,000 per year in 1981 dollars.

It should be pointed out that the costs presented in this estimate are conservatively high and are not necessarily applicable to all potential developers. Certain costs can be reduced depending upon the individual developer. There could be some cost savings if suitable used equipment could be acquired or if the developer could provide labor and materials at a lower cost.

VIII. PROJECT BENEFITS

Benefits from the possible hydro facility are based on the amount of energy made available to the local transmission system. The Public Utility Regulatory Policies Act of 1978 (PURPA) requires a utility to purchase energy offered for sale by a qualifying facility. The value of this energy is determined using the rates adopted by TVA under its Dispersed Power Production Policy. Under the program's current rate structure for plants having 100 kW or greater capacity, the energy price

BURGESS FALLS DAM

HYDROELECTRIC PLANT REHABILITATION

Estimate of Cost[1]

General Yard Improvements	$ 9,000
Powerhouse	55,000
Spillway	31,000
Intake	56,000
Water Conductor	83,000
Turbine-Generator and Electrical Equipment	358,000
Construction Facilities	74,000
Total Direct Construction	666,000
Field General Expense	47,000
Contingency	47,000
Total Field Construction	760,000
Interest During Construction	54,000
Total Construction	814,000
Engineering Design	100,000
Administration	36,000
Total Project	$950,000

[1]Total project cost is based on 1981 dollars. This estimate does not include the primary reclosure and the 13.2 kV/480-volt transformer.

Figure 8: Cost Estimate

is 4.489 cents/kWh during peak periods, and 2.826 cents/kWh during off-peak periods. Since plant operation at Burgess Falls Dam would use the available inflow without regard to the time of day, the weighted average of these two rates, 3.407 cents/kWh, has been used to evaluate the energy production. Using this value, the potential average annual generation of 1,300,000 kWh at Burgess Falls Dam is worth approximately $44,300. This energy value is subject to change in accordance with the adjustment provisions of TVA's wholesale power contracts.

IX. ECONOMIC ANALYSIS

The feasibility of restoring the hydro facilities at Burgess Falls Dam was evaluated by comparing the present worth of the project's benefits and costs over an assumed 35-year economic life of the project to form a Benefit-Cost (B/C) ratio. Benefits are based entirely on the amount of energy supplied to the local transmission system. Project costs are comprised of the capital cost of the rehabilitation work and the present worth of operation and maintenance costs. For the city of Cookeville, the most likely developer, a discount rate of 10 percent was assumed since this is the approximate municipal bond rate.

The present worth of power benefits and operation and maintenance costs was computed for two different economic forecasts. An escalation rate of 10.5 percent was assumed for the first eleven years in the high forecast and 10.0 percent for the remainder of the economic life. In the low forecast 7.3 percent escalation was assumed for the first 11 years, 5.5 percent for the next 8 years, and 6.0 percent for the last 16 years.

The present worth of the power benefits and costs for the high forecast equals $1,464,100 and $1,280,300, respectively, resulting in a B/C ratio of 1.14. The low forecast present worth values for project benefits and costs are $868,000 and $1,145,800, respectively, which yield a B/C ratio of 0.76. Since actual values are expected to fall in between these numbers, this analysis is not sufficient to make a decision on implementation. A potential developer would need to perform a detailed financial analysis to determine if he could utilize available tax benefits from the project to produce a satisfactory return on investment.

Figure 9 shows the sensitivity of the B/C ratio to varying discount and escalation rates assuming a 35-year economic life. The B/C ratio can be significantly affected by a different prediction of the future state of the economy, a different applicable discount rate, and reduction in the total project cost.

X. ENVIRONMENTAL ASSESSMENT

The environmental effects of hydro projects, which have relatively small existing dams and operate as run-of-river plants, are most often minimal. This concept is consistent with independent studies made by several organizations. One such study was done by a consultant for assisting the Federal Energy Regulatory Commission (FERC) in proposing regulations to exempt certain projects from licensing as provided in Part I of the Federal Power Act. To qualify for such exemption, a candidate must be an existing dam, have a total installed capacity of less than 5 MW, and meet the following conditions:

1. Repair or reconstruction of the dam must not raise the normal maximum surface elevation of the impoundment.
2. There must not be significant existing upstream or downstream passage of fish.
3. Operation of the dam for hydropower purposes must not change the normal storage and release pattern of the impoundment.
4. The discharge from the powerhouse must be located no more than 300 feet from the toe of the dam.
5. The project must not involve construction at or alteration of a historic site.
6. If the project requires a new transmission line, it must be 69 kV or less, and the line must be shorter than one mile if located on a new right-of-way.
7. The project must not adversely affect a Federally-designated critical habitat or a Federally designated threatened or endangered species.
8. The project must not cause violations of applicable State or Federal water quality standards.

The possible redevelopment of the Burgess Falls Dam meets all of the above conditions, except the first condition. Presently the normal water surface of the reservoir is at the spillway crest (El. 872.6). Under the redevelopment plan, the spillway gates would be repaired for use and lowered in place in order to gain an additional ten feet of head. This would change the present conditions, but would not exceed the original reservoir design level. Therefore, it is anticipated that long term environmental effects would not be a significant deterrent to the rehabilitation.

Short term environmental effects caused by the construction, such as an increase in the turbidity of the water and construction noise, would be minimized by proper construction techniques and would be only temporary.

XI. CONCLUSIONS AND RECOMMENDATIONS

Based on the analysis made in this study, the feasibility of restoring the power facilities at Burgess Falls Dam would be marginal. Depending upon the economic forecast assumed, the Benefit-Cost ratio ranges between 0.76 and 1.14 at a 10 percent discount rate. The developer should be aware that there could be negative cash flows for the first several years of operation until escalating benefits reach and surpass costs.

Favorable economics would depend on the developer's ability to reduce costs, his ability to secure low interest financing, and his financial situation being such that he could take advantage of tax benefits available to small hydro investors. It is recommended that a detailed financial analysis be performed to help determine whether or not to proceed with redevelopment.

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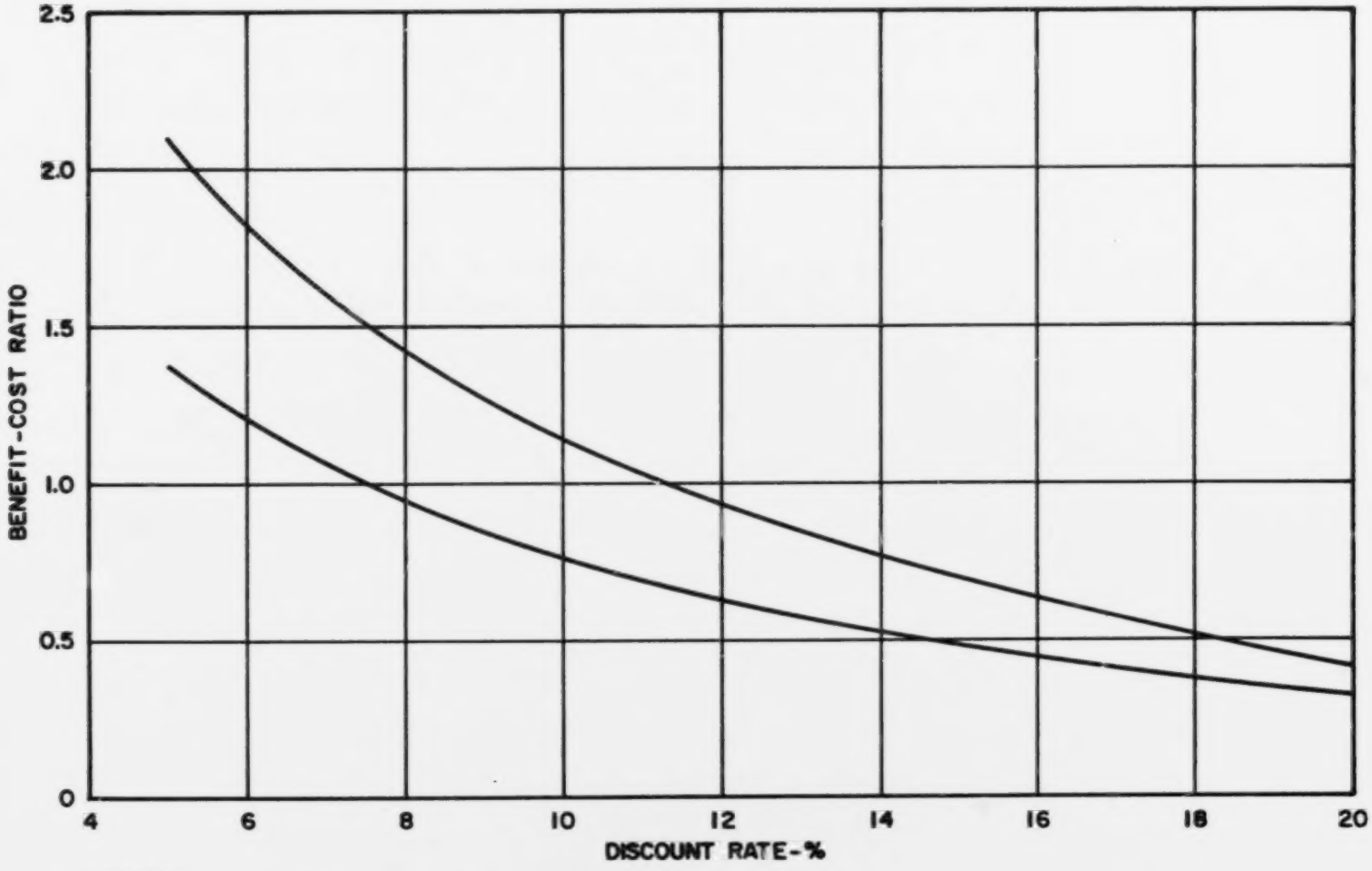
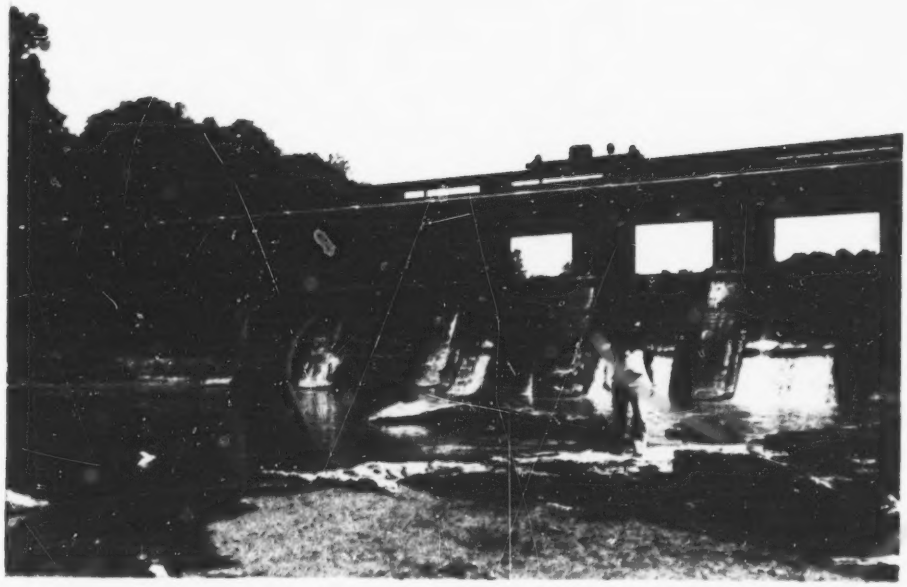
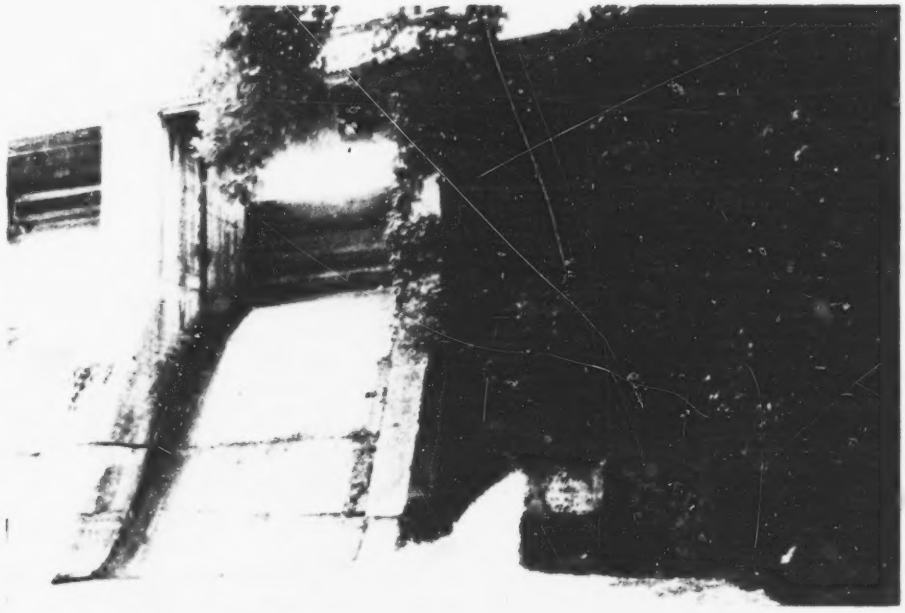


Figure 9. Discount Rate vs Benefit-Cost Ratio



Downstream view of dam



Downstream view of sluice and penstock

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Burgess Falls, approximately
one mile downstream of dam

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APPENDIX C

DESOTO STATE PARK DAM

APPENDIX C

FEASIBILITY REPORT - DESOTO STATE PARK DAM

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SUMMARY OF PRINCIPAL FEATURES

DeSoto State Park Dam

Location
On the West Fork Little River approximately 8 miles northeast of Fort Payne, in DeKalb County, Alabama.

Owner
State of Alabama

Streamflow	
Drainage area	35.4 sq. miles
Average discharge	77 cfs
Tailwater	
Normal operating	El. 1519.9
Minimum	El. 1519.3
Operating Heads (net)	
Maximum	110.5 ft
Minimum	103.0 ft
Rated	106.3 ft
Dam	
Type	concrete buttress
Length	217 ft
Height	20 ft
Top of spillway	El. 1630.8
Sluice	2.6 ft x 2.6 ft opening controlled by slide gate
Possible Power Facilities	
Intake	8 ft x 12 ft reinforced concrete
Penstock	440 ft steel pipe, 4 ft in diameter
Powerhouse	18 ft x 23 ft reinforced concrete
Hydraulic turbines	
Number	one
Type	horizontal Francis
Runner diameter	22 in
Generator	
Type	induction, horizontal shaft
Rating	700 kW
Plant output	
Average annual energy	2,000,000 kWh
Cost	
Total project cost	$1,530,000
Cost per kW	$2,200

SUMMARY

This report presents the results of a study to determine the feasibility of restoring the hydroelectric generating facilities at DeSoto State Park Dam in DeKalb County, Alabama. The costs used for this report reflect construction costs experienced by TVA including overheads normally used in TVA accounting procedures and may or may not apply to a developer.

The evaluation of several alternative plans using TVA costs and benefits and an assumed discount rate indicates that the redevelopment of the DeSoto State Park Dam is not currently economically feasible.

I. INTRODUCTION

The purpose of this report is to investigate the possibility of restoring hydroelectric power generation facilities at the DeSoto State Park Dam on the West Fork Little River in DeKalb County, Alabama.

This report is part of the second phase of TVA's Small Hydro Program which was begun in 1979 to investigate the potential for small scale hydroelectric production in the Tennessee Valley region. The first phase, which was completed in June 1980, consists of an inventory and screening of existing non-Federal dams in the Tennessee Valley and the TVA power service area. The second phase consists of more detailed feasibility studies on ten of the most promising sites based on the results of the reconnaissance phase.

Included in the feasibility analysis for DeSoto State Park Dam is a detailed cost estimate, evaluation of project benefits, and computation of a Benefit-Cost ratio. A potential developer can use these to help make a decision regarding whether or not to proceed with rehabilitation of the facility.

II. SITE HISTORY

DeSoto State Park Dam, also known as the A. A. Miller Dam, is part of an old hydroelectric facility which used the dam to divert flow in the West Fork Little River through a penstock downstream to a powerhouse to utilize the fall in the river. It was the first hydroelectric installation in northeast Alabama.

The dam was completed in 1925 and was initially 10 feet high. Later it was raised to 20 feet in height to increase the size of the reservoir behind the dam.

In the original power installation, a penstock approximately 48 inches in diameter led from the dam near the right abutment approximately 300 feet downstream to a powerhouse located below DeSoto Falls on the right bank. The powerhouse contained two 360 hp units and was part of a power system which supplied electricity to the surrounding area. Generation from the hydroplant was supplemented by diesel powered generators at another location. All that now remains of the facility is the concrete powerhouse foundation.

III. SITE DESCRIPTION

A. General

DeSoto State Park Dam is located on the West Fork Little River in DeKalb County, Alabama, approximately eight miles northeast of Fort Payne (see Figures 1 and 2). The site is in DeSoto State Park which is in an old resort area where many vacation homes are located. Access is by narrow paved roads off State Highway 89.

B. DeSoto Falls

A major attraction in the Park is DeSoto Falls which is located about 200 feet downstream of DeSoto State Park Dam (see Figure 3). Here the West Fork Little River tumbles approximately 80 feet into a pool which is surrounded by a scenic gorge. Between the dam and DeSoto Falls is an intermediate falls where the river drops 20 feet. The area at the site is

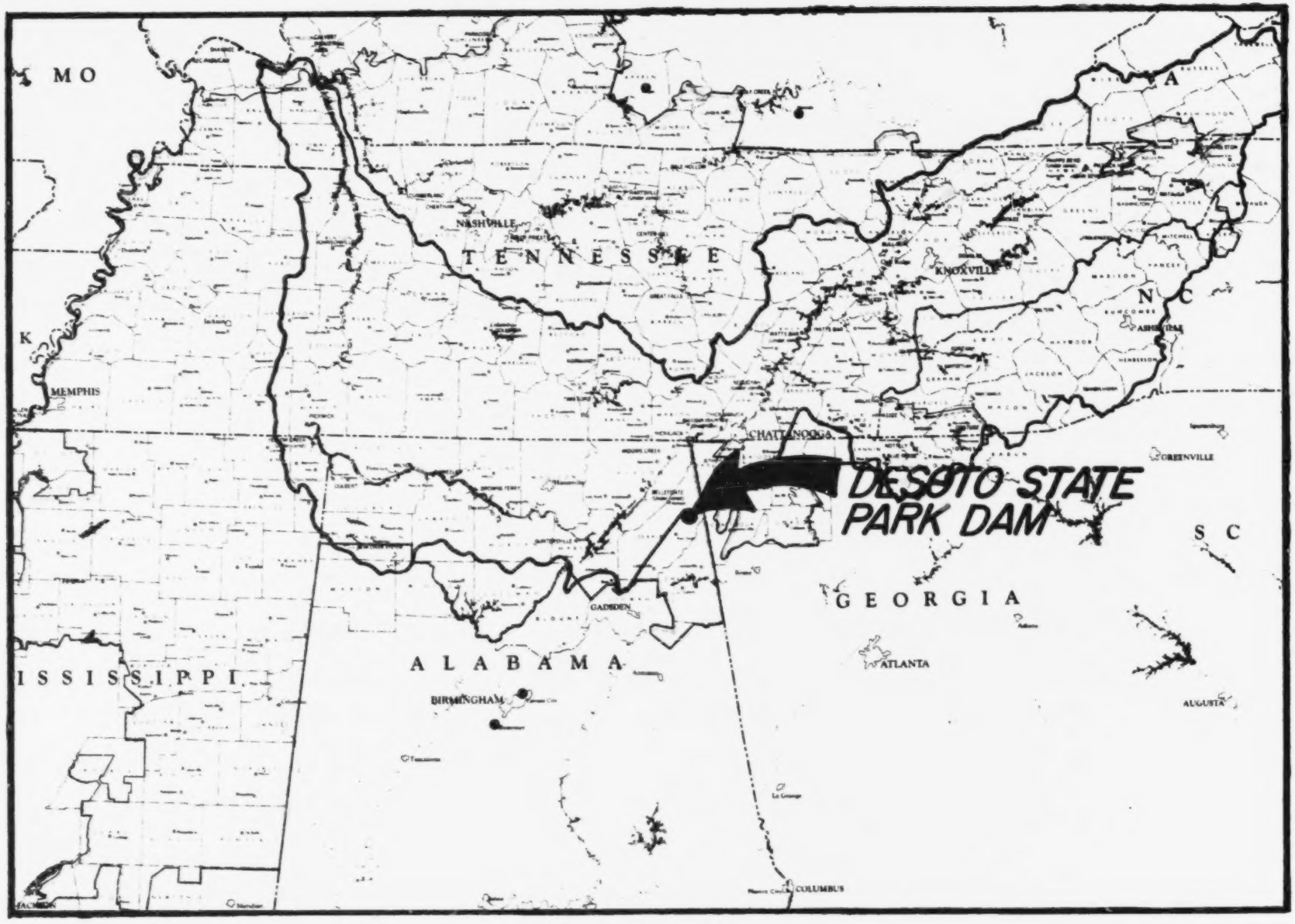

Figure I. Location Map

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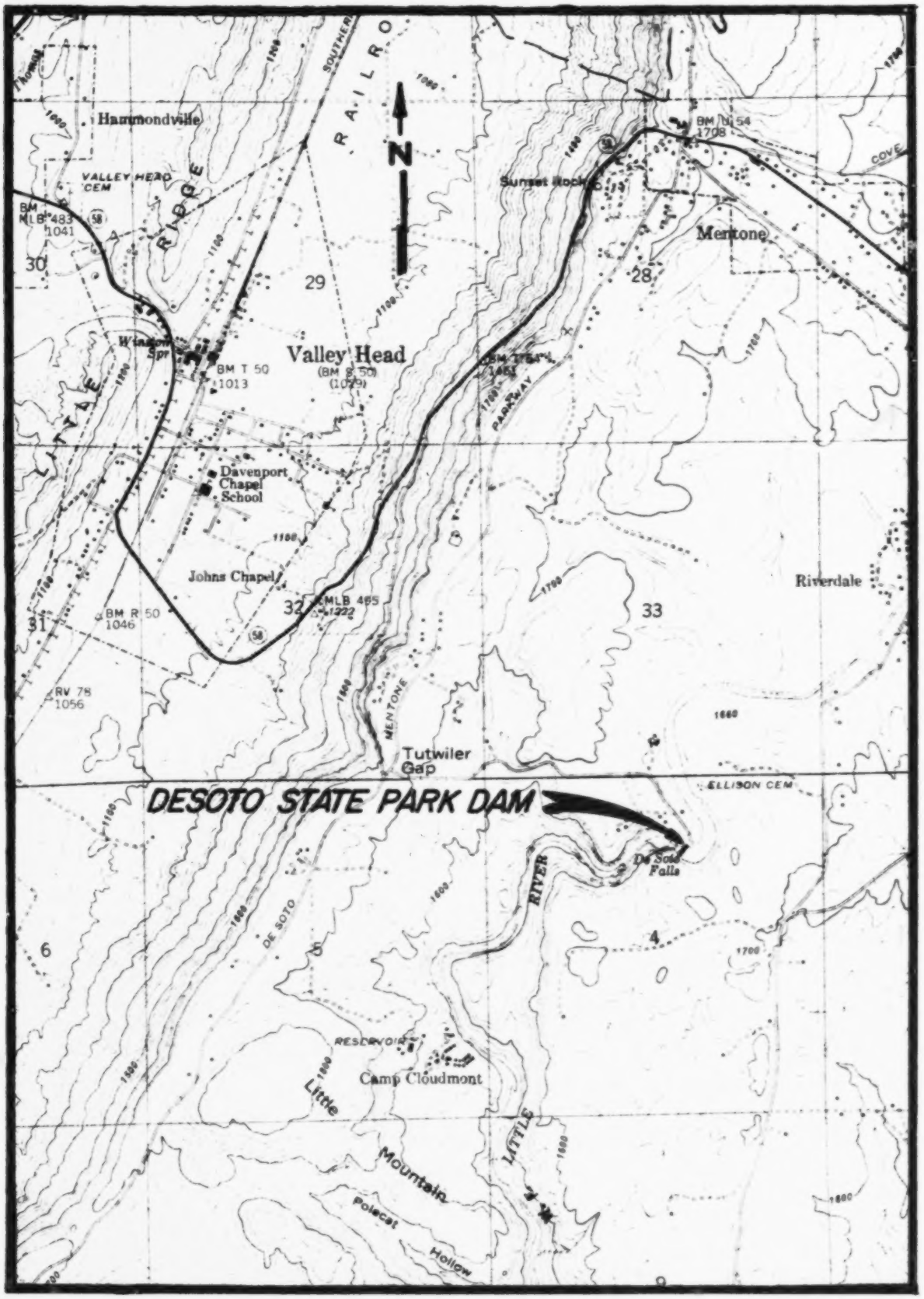

Figure 2. Vicinity Map

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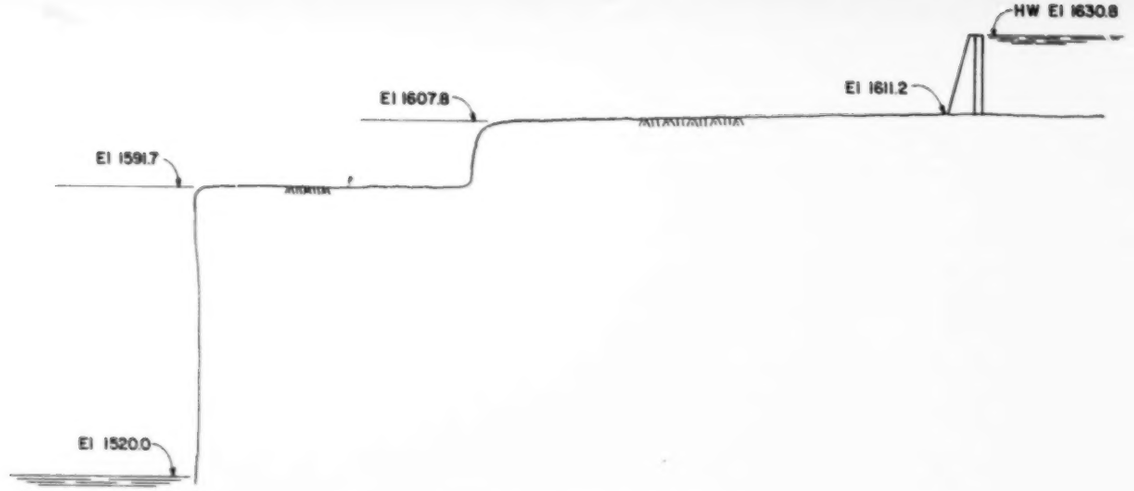
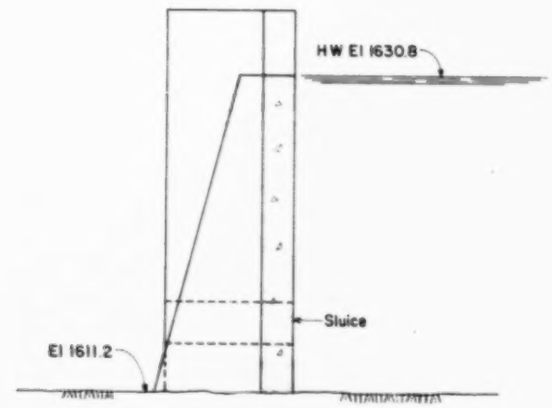
PLAN

Scale 20 0 20 40 Feet



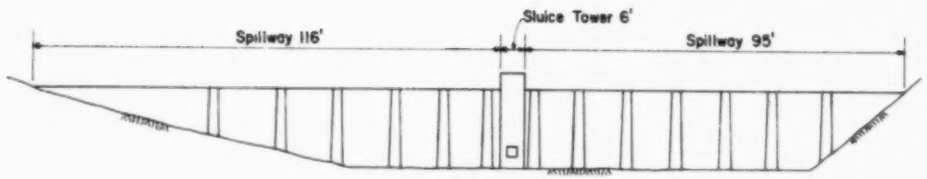
PROFILE ALONG ℄ OF RIVER

Scale 20 0 20 40 Feet



SECTION A-A

Scale 5 0 5 10 Feet



DOWNSTREAM ELEVATION

Scale 20 0 20 40 Feet

Figure 3. Existing Facilities
DeSoto State Park Dam

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used for sightseeing, hiking, swimming, boating, and picknicking. Facilities at the site include picnic tables and restrooms.

C. Dam

The dam is a concrete buttress structure 20 feet high and 217 feet long founded on solid rock. It is in good condition, having been maintained by the Park. The reservoir behind the dam is small and contains no appreciable storage or accumulation of silt.

D. Sluice

For the purpose of draining the reservoir, a 24-ft high concrete sluice tower is located near the middle of the dam. A hand crank on top of the tower controls a 2.6 ft x 2.6 ft steel slide gate.

IV. HYDROLOGY AND HYDRAULICS

Land drained by the West Fork Little River is largely agricultural in use and totals 35.4 square miles at DeSoto State Park Dam. Based on historical data from a downstream streamflow gage, the average flow at the dam is 77 cfs. In extremely dry conditions there is no flow in the river.

A flow duration curve was generated using flows adjusted by relative drainage areas from a USGS streamflow gage on the Little River near Jamestown, Alabama. The drainage area at this gage is 121 square miles, and records are available from October 1928 to April 1932 and from May 1935 to September 1949. Figure 4 is the adjusted duration of flow curve for the West Fork Little River at DeSoto State Park Dam.

Due to the low hazard potential of the DeSoto State Park Dam, the 100-year flood has been selected as the design flood for this study. A flood of this magnitude would correspond to a flow of about 10,000 cfs and would overtop the dam by about 5 feet. Failure of the dam would pose no downstream hazard.

V. PROJECT DEVELOPMENT

In selecting the best redevelopment plan for the project, several alternatives were considered. Power studies and brief cost estimates were performed for each alternative so that the most feasible plan could be selected and the optimum installed capacity determined.

The first alternative considered was a prefabricated hydroelectric generating station. It could be located in the streambed between the dam and DeSoto Falls either immediately below the dam or below the intermediate falls to take advantage of the additional 20 feet of head. Civil costs at this installation would be minimized by using the existing sluice tower as the intake. Environmental impacts would also be minimized since operation of the plant would not affect DeSoto Falls. The other alternative studied was a powerhouse located below DeSoto Falls utilizing a horizontal Francis runner. This would be similar to the original power facility.

The alternative selected as being the most feasible was a 22-inch horizontal Francis turbine manufactured by the James Leffel and Company which would be housed in a powerhouse below DeSoto Falls just downstream of the original powerhouse location (see Figures 5 and 6). Project features include a new concrete intake structure near the right abutment of the dam, a 4-ft diameter steel penstock 440 feet long which would be

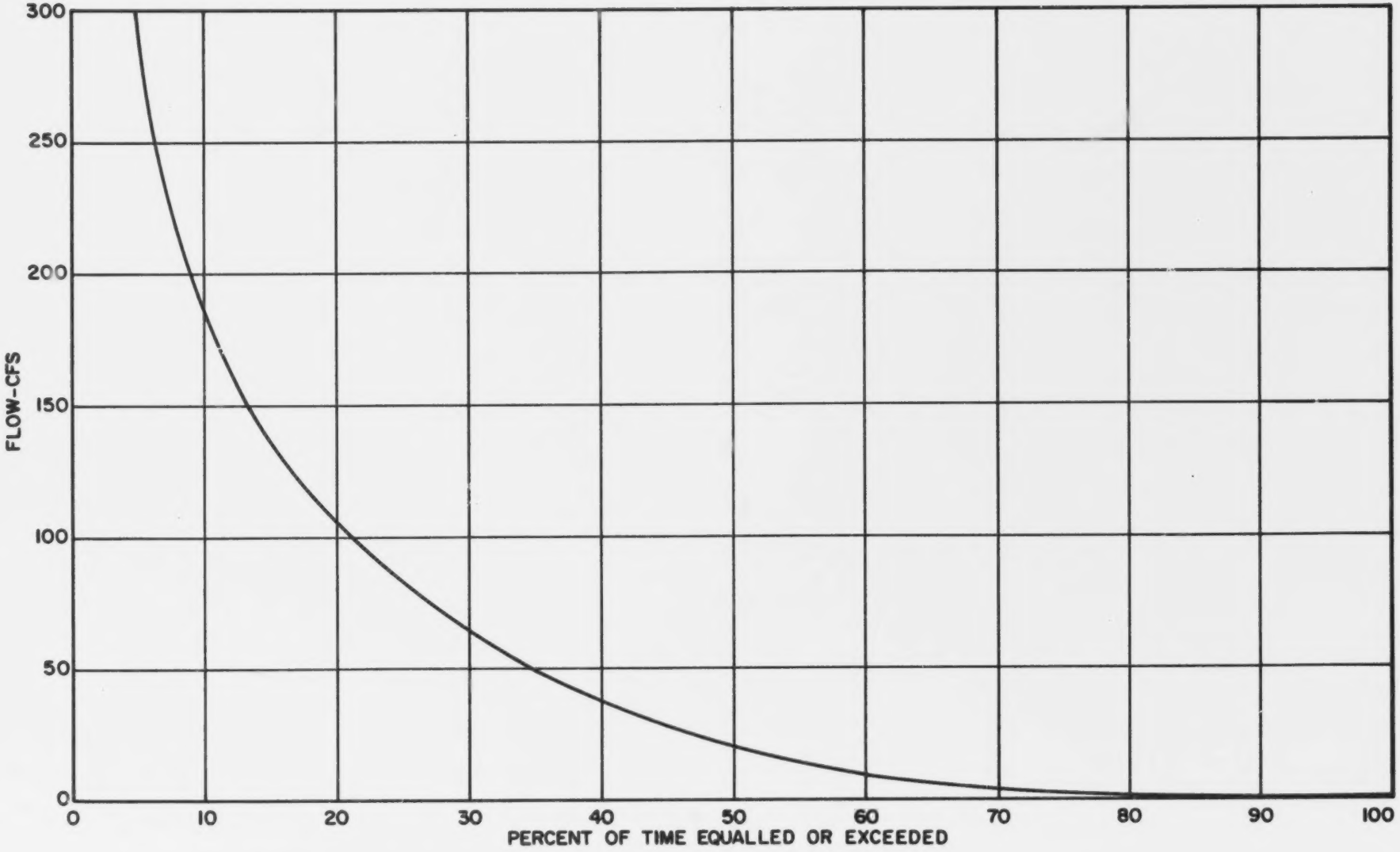

Figure 4. Duration of Flow

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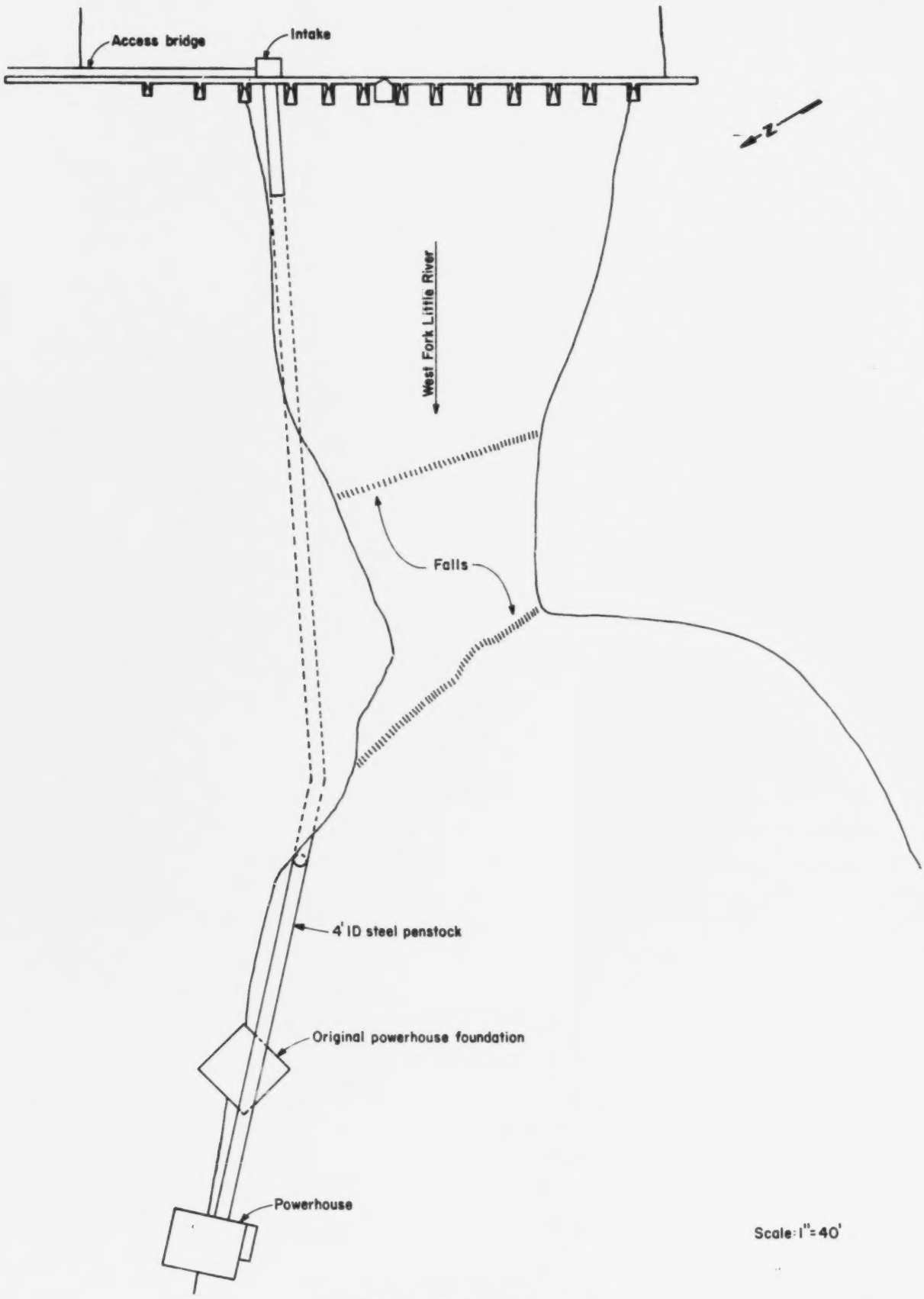

Figure 5. Possible Site Plan

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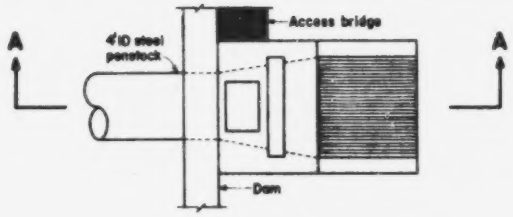
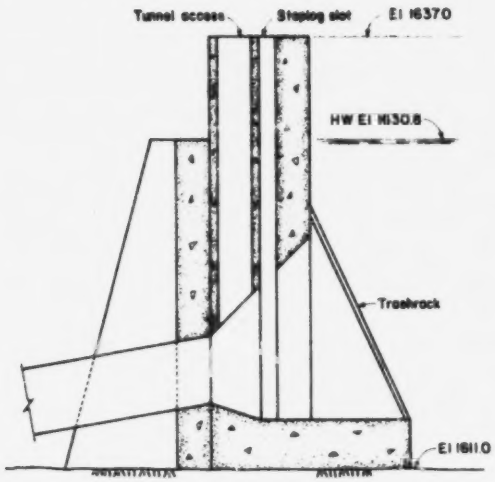
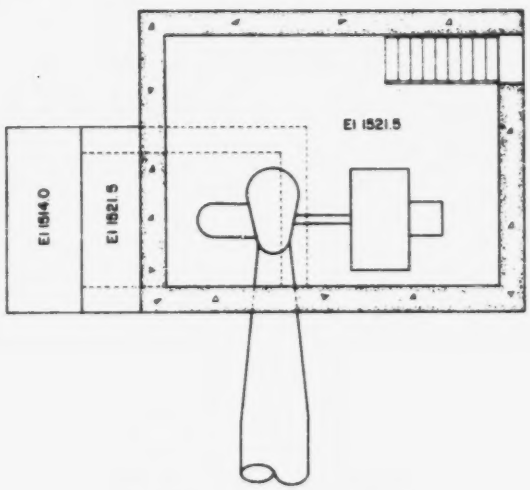


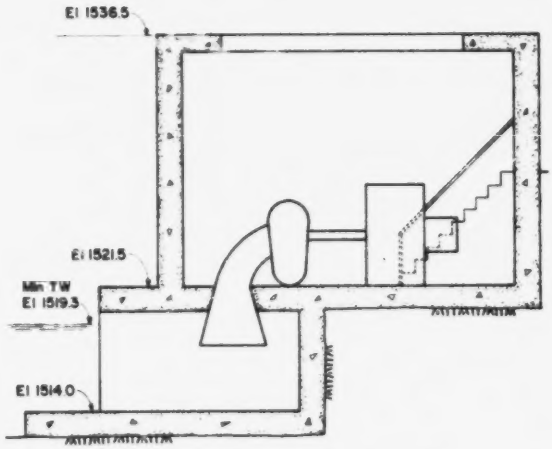
PLAN–INTAKE



SECTION A-A



PLAN–GENERATOR FLOOR



SECTION THRU POWERHOUSE

Figure 6. Possible Redevelopment Plan

placed underground from the dam to DeSoto Falls, and a new concrete powerhouse. The turbine would be directly coupled to an induction generator rated at 700 kW. Access into the powerhouse area would be by a steel stairway leading down from the top of the escarpment. Automatic headwater level control equipment would prevent reservoir drawdown during low flow periods.

An installation below DeSoto Falls presents several problems. First, the project is in a State park and operation of the plant would significantly disrupt DeSoto Falls, a major attraction in the Park, by diverting water around the falls. Power studies in this report assume that streamflow up to unit capacity flow is available for power generation. However, restrictions allowing generation only at night or during the off-season could be imposed to reduce this impact. Such restrictions would reduce the average annual generation of the project.

Also, the steep terrain characterizing the area would cause construction problems. Because of the difficulties in providing an access road to the powerhouse area, all access would be from the top of the escarpment directly over the site. A crane would be used to move all equipment and materials in and out of the site. This arrangement would especially hamper construction of a cofferdam and the powerhouse excavation. The severe slope and small size of the construction area would also adversely affect construction activities.

VI. POWER PRODUCTION

It is assumed that operation of the possible hydroplant would be run-of-river. The potential power was determined utilizing the duration of

flow curve shown in Figure 4. Usable flow under the curve was divided into several increments and average annual generation was computed by summing the potential energy from each increment under the curve. For this computation, a specific efficiency value was assigned to each increment of flow based on manufacturer's unit performance curves, and net heads were computed using a tailwater curve and accounting for losses in the system.

Average annual energy produced by the 22-inch horizontal Francis turbine unit was estimated to be 2,000,000 kWh. At full gate (100 cfs) the unit is rated at 700 kW with an overall efficiency of 78 percent at 106.3 ft net head. For approximately 60 percent of the time, flow conditions would not be suitable for plant operation.

VII. PROJECT COSTS

The project cost in 1981 dollars of the most feasible redevelopment plan is estimated to be $1,530,000 and is comprised of estimates of equipment and structural costs, interest during construction, contingencies, and overheads. The major items in the estimate are the intake and powerhouse structures, steel penstock, and mechanical and electrical equipment. A summary of these costs is shown in Figure 7. The manufacturer supplied the cost of the turbine, generator, and scroll case and other costs are based on TVA costs. Operation and maintenance expenses are assumed to be $20,000 per year in 1981 dollars.

It should be recognized that these costs are conservatively high and may not be applicable to all potential developers. There could be some cost savings if a developer could acquire suitable used equipment or if he could provide labor and materials at a lower cost.

DESOTO STATE PARK DAM

HYDROELECTRIC PLANT REHABILITATION

Estimate of Cost[1]

General Yard Improvements	$ 7,000
Powerhouse	219,000
Intake	54,000
Water Conductors	79,000
Turbine - Generator Equipment	442,000
Electrical Equipment	135,000
Construction Facilities	117,000
Total Direct Construction	1,053,000
Field General Expense	74,000
Contingency	100,000
Total Field Construction	1,227,000
Interest During Construction	86,000
Total Construction	1,313,000
Engineering Design	158,000
Administration	59,000
Total Project	$1,530,000

[1]Total project cost is based on 1981 dollars. This estimate does not include the primary reclosure or the 13.2 kV to 480 V transformer.

Figure 7: Cost Estimate

VIII. PROJECT BENEFITS

Benefits from the possible hydro facility are based on the amount of energy made available to the local transmission system. The Public Utility Regulatory Policies Act of 1978 (PURPA) requires a utility to purchase energy offered for sale by a qualifying facility. The value of this energy is determined using the rates adopted by TVA under its Dispersed Power Production Policy. Under the program's present rate structure for plants having 100 kW or greater capacity, the price for on-peak electricity is 4.489 cents per kWh and 2.826 cents per kWh for off-peak electricity. Since plant operation at DeSoto State Park Dam would use the available inflow without regard to the time of day, the weighted average of these two rates, 3.407 cents per kWh, has been used to evaluate the energy production. Using this value, the potential average annual generation of 2,000,000 kWh at DeSoto State Park Dam is worth approximately $68,100. The energy value is subject to change in accordance with the adjustment provisions of TVA's wholesale power contracts.

IX. ECONOMIC ANALYSIS

The feasibility of restoring the hydro facilities at DeSoto State Park Dam was evaluated by comparing the present worth of the project's benefits and costs over an assumed 35-year economic life of the project to form a Benefit-Cost (B/C) ratio. Benefits are based entirely on the amount of energy supplied to the local transmission system. Project costs are comprised of the capital cost of the rehabilitation work and the present worth of operation and maintenance costs. A discount rate of 15 percent,

which is the approximate current prime rate, was assumed since the most likely developer would be a private investor.

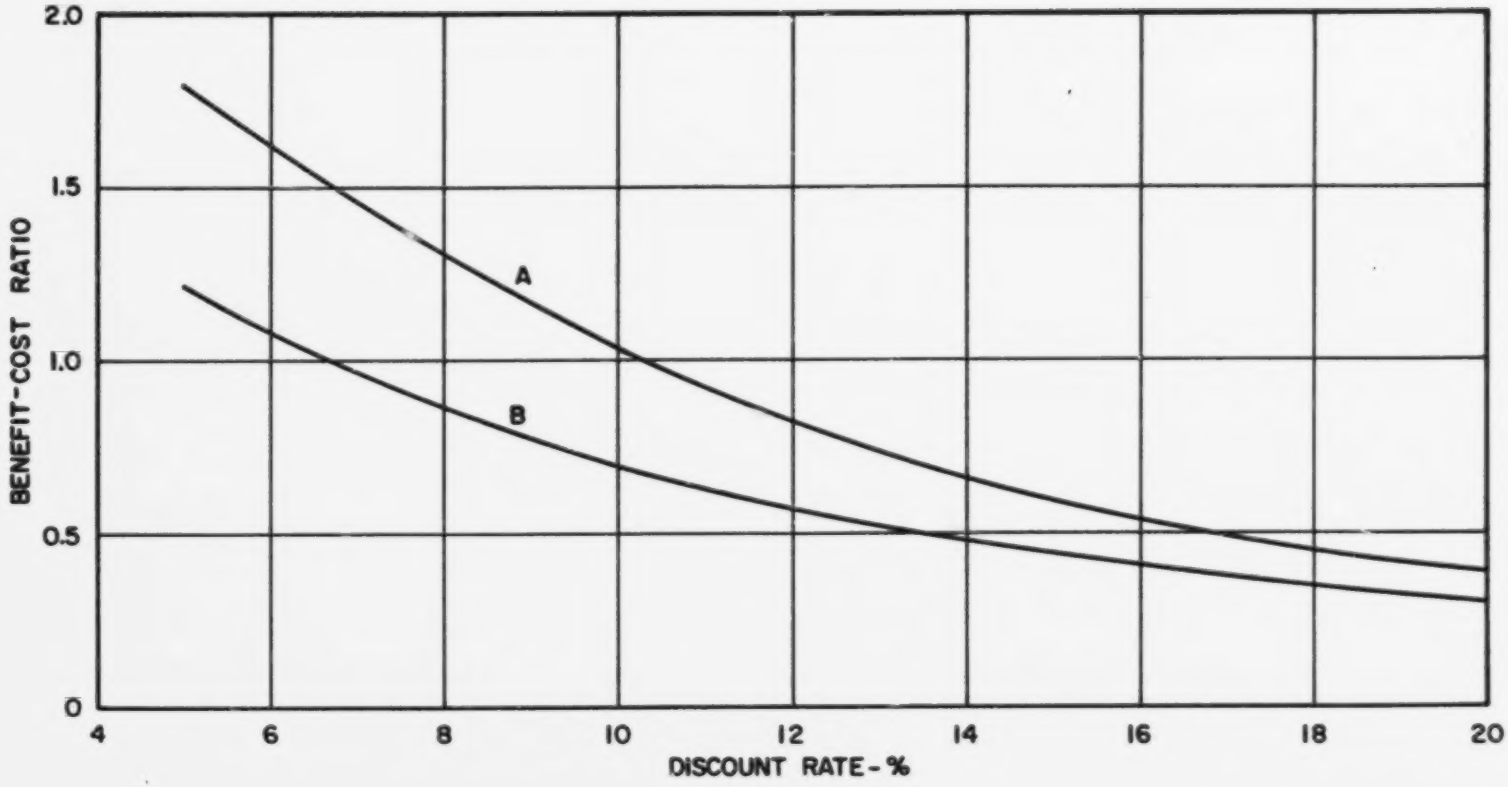
The present worth of power benefits and operation and maintenance costs was computed for two different economic forecasts. An escalation rate of 10.5 percent was assumed for the first eleven years in the high forecast and 10.0 percent for the remainder of the economic life. In the low forecast 7.3 percent escalation was assumed for the first 11 years, 5.5 percent for the next 8 years, and 6.0 percent for the last 16 years.

The present worth of the project benefits and costs for the high forecast equals $1,111,000 and $1,856,000, respectively, resulting in a B/C ratio of 0.60. The low forecast present worth values for project benefits and costs are $763,000 and $1,754,000, respectively, which yield a B/C ratio of 0.44. Based on these values the project is not economically feasible. However, it is emphasized again that the assumptions made in this analysis do not necessarily apply to potential developers.

Figure 8 shows the sensitivity of the B/C ratio to varying discount and escalation rates assuming a 35-year economic life. The B/C ratio can be significantly affected by a different prediction of the future state of the economy, a different applicable discount rate, and reduction in the total project cost.

X. ENVIRONMENTAL ASSESSMENT

The environmental effects of hydro projects, which have relatively small existing dams and operate as run-of-river plants, are most often minimal. This concept is consistent with independent studies made by several organizations. One such study was done by a consultant for



LEGEND:
A - High escalation rate for benefits and O&M costs
B - Low escalation rate for benefits and O&M costs

Figure 8. Discount Rate vs Benefit-Cost Ratio

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assisting the Federal Energy Regulatory Commission (FERC) in proposing regulations to exempt certain projects from licensing as provided in Part I of the Federal Power Act. To qualify for such exemption, a candidate must be an existing dam, have a total installed capacity of less than 5 MW, and meet the following conditions:

1. Repair or reconstruction of the dam must not raise the normal maximum surface elevation of the impoundment.
2. There must not be significant existing upstream or downstream passage of fish.
3. Operation of the dam for hydropower purposes must not change the normal storage and release pattern of the impoundment.
4. The discharge from the powerhouse must be located no more than 300 feet from the toe of the dam.
5. The project must not involve construction at or alteration of a historic site.
6. If the project requires a new transmission line, it must be 69 kV or less, and the line must be shorter than one mile if located on a new right-of-way.
7. The project must not adversely affect a Federally-designated critical habitat or a Federally-designated threatened or endangered species.
8. The project must not cause violations of applicable State or Federal water quality standards.

The possible redevelopment of the DeSoto State Park Dam meets all of the above conditions except (4). Discharge from the powerhouse would reenter the river approximately 360 feet downstream of the dam, causing this stretch of river to have little or no flow approximately 20 percent of the time.

From a wildlife or water quality standpoint, such a reduction in flow should not cause a significant impact. There are no special fish or wildlife populations which would be disturbed by operation of the plant, and there is no pollutive discharge into this stretch of river which would affect water quality.

However, operating the diversion project would significantly affect DeSoto Falls by interrupting the flow over the falls. Disrupting a main attraction in the Park would probably not be tolerated. One alternative for reducing this impact would be to operate the plant only at night or during the off-season. However, limiting the plant's operating schedule would reduce the average annual energy production and thus the project's benefits.

Short-term environmental effects caused by construction such as an increase in the turbidity of the water, construction noise, and interruption of recreational activities, would be minimized by proper construction techniques and would be only temporary.

XI. CONCLUSIONS AND RECOMMENDATIONS

Based on the analysis made in this study, restoring the hydroelectric generating facilities at DeSoto State Park Dam does not appear to be feasible. Depending upon the economic forecast assumed, the Benefit-Cost ratio ranges between 0.44 and 0.60 at a 15 percent discount rate.

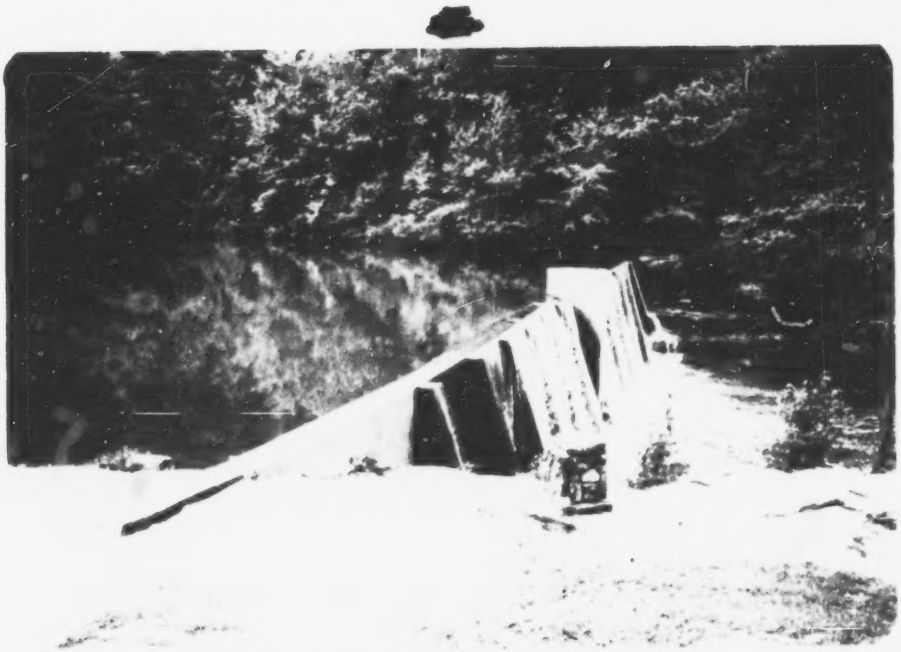
The redevelopment of DeSoto State Park Dam is unattractive for several reasons. First, a major obstacle is the impact of diverting the river around DeSoto Falls. As mentioned in earlier sections, such operation would significantly diminish the aesthetics of the falls and probably

would not be permitted. Any restrictions imposed on plant operation to mitigate this impact would reduce energy production and thus the Benefit-Cost ratio. Second, the economics are unfavorable. The feasibility of a small hydro project depends to a large extent on the site already having many of the facilities required for power generation. At DeSoto State Park Dam only the dam from the original facility could be used, so considerable cost would be incurred in providing a new intake, penstock, and powerhouse. Difficulties in accessing the site due to the impracticality of providing a road to the powerhouse area would also increase the cost of construction. Also, the value of energy benefits in the TVA area is less than in most other parts of the country due to TVA's comparatively lower electric power rates. As a result of this, there could be negative cash flows for the first several years of operation until escalating benefits reach and surpass costs.

Several regulations apply to small hydro projects and must be complied with. A developer is required to obtain the licenses and permits needed to construct and operate the project from the appropriate organizations on the local, State, and Federal levels of government.

It should be pointed out again that assumptions made in this analysis may or may not apply to a potential developer. More attractive economics would depend on a developer's ability to reduce costs, to secure low interest financing, and to take advantage of tax benefits available to small hydro investors.

Because of the above reasons, it is recommended that further consideration for the redevelopment of the DeSoto State Park Dam site be delayed until a significant change occurs in the conditions that impact the economics and until an acceptable solution for minimizing the impact on DeSoto Falls is determined.



View of dam

View of DeSoto Falls

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APPENDIX D

EYE MILES DAM

APPENDIX D

FEASIBILITY REPORT - EVE MILLS DAM

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SUMMARY OF PRINCIPAL FEATURES

Eve Mills Dam

Location
On Fork Creek in Monroe County, Tennessee

Owner
Mrs. Rhea Ghormley Alexander

Streamflow	
Drainage area	31.8 sq. miles
Average discharge	54 cfs
Tailwater	
Normal operating	El. 88.1[1]
Minimum	El. 87.2[1]
Operating Heads (net)	
Maximum	10.3 ft
Minimum	3.0 ft
Rated	9.0 ft
Dam	
Type	concrete gravity
Length	160 ft
Height	10 ft
Top of spillway	El. 97.9[1]
Sluices	2, 3-ft x 3-ft
Possible Power Facilities	
Existing intake channel	40-ft open flume
Existing shed	20-ft x 60-ft
Existing mill building	30-ft x 80-ft
Existing hydraulic turbines	
Number	one
Type	Leffel Size 35 Improved Vertical Samson
Rated output	67 hp
Generator	
Type	induction
Rating	33 kW
Plant output	
Average annual energy	100,000 kWh
Cost	
Total project cost	$110,000
Cost per kW	$3,300

[1]Elevation based on arbitrary datum elevation 100.0

SUMMARY

This report presents the results of a study to determine the feasibility of adding hydroelectric generating facilities to Eve Mills Dam. The costs used for this report reflect construction costs experienced by TVA including overheads normally used in TVA accounting procedures and may or may not apply to a developer.

The analysis using TVA costs and benefits and an assumed discount rate indicates that the redevelopment of Eve Mills Dam is not presently economically feasible. The project would look more attractive if a developer could reduce costs, obtain financing at a lower discount rate, and perform much of the construction, operation, and maintenance of the plant himself. More favorable economics could be achieved if the developer could take advantage of tax incentives available to small hydro investors.

I. INTRODUCTION

The purpose of this report is to investigate the possibility of adding hydroelectric power facilities at Eve Mills Dam on Fork Creek in Monroe County, Tennessee.

This report is part of the second phase of TVA's Small Hydro Program which was begun in 1979 to investigate the potential for small scale hydroelectric production in the Tennessee Valley Region. The first phase, which was completed in June 1980, consists of an inventory and screening of existing non-Federal dams in the Tennessee Valley and the TVA power service area. The second phase consists of more detailed feasibility studies on ten of the most promising sites based on the results of the reconnaissance phase.

The report has three major elements: possible power installations and their costs, the amount and worth of possible power production, and an economic evaluation of project feasibility in light of these costs and benefits.

II. SITE HISTORY

There have been grist mills at the Eve Mills site since the early years of the nineteenth century. The present mill building was built in 1875 following a large storm which destroyed a previous mill. Following the destruction of the timber dam by a flood in 1946, the owner's father, Mr. Samuel Ghormley, built the present concrete dam and turbine pit and added the electrically powered seed cleaning equipment. Presently the water powered grist mill is operated occasionally on a non-commercial basis

and the electric powered seed cleaner operates seasonally to meet local demand. Electricity has never been generated at the site. Because of the mill's historical significance, the present owner is interested in preserving the mill and has applied to have the mill placed on the National Register of Historic Places.

III. SITE DESCRIPTION

A. General

The Eve Mills site consists of a dam, grist mill, and seed cleaning facility located on Fork Creek in rural Monroe County, Tennessee, about eight miles north of the county seat of Madisonville (see Figures 1 and 2). About 2.5 miles below the site the creek enters Tellico Lake on the Little Tennessee River. The site is reached via secondary roads off either U.S. Highway 11 through Loudon or U.S. Highway 411 through Madisonville. The owner of the facility is Mrs. Rhea Ghormley Alexander of Loudon, Tennessee.

B. Mill

As indicated in Figure 3, there are two mill buildings at Eve Mills. The larger building containing the seed cleaning machinery and a small grist mill is a single story frame building about thirty feet wide by eighty feet long. During the March 1973 flood the pile foundation of the building was undermined and required extensive repairs. Recently the structure has been rewired to comply with the electrical code. The building is structurally sound and is in fair condition overall. Attached to this building is a small dilapidated structure housing the remains of an earlier grist mill. This mill was never driven by the existing turbine.

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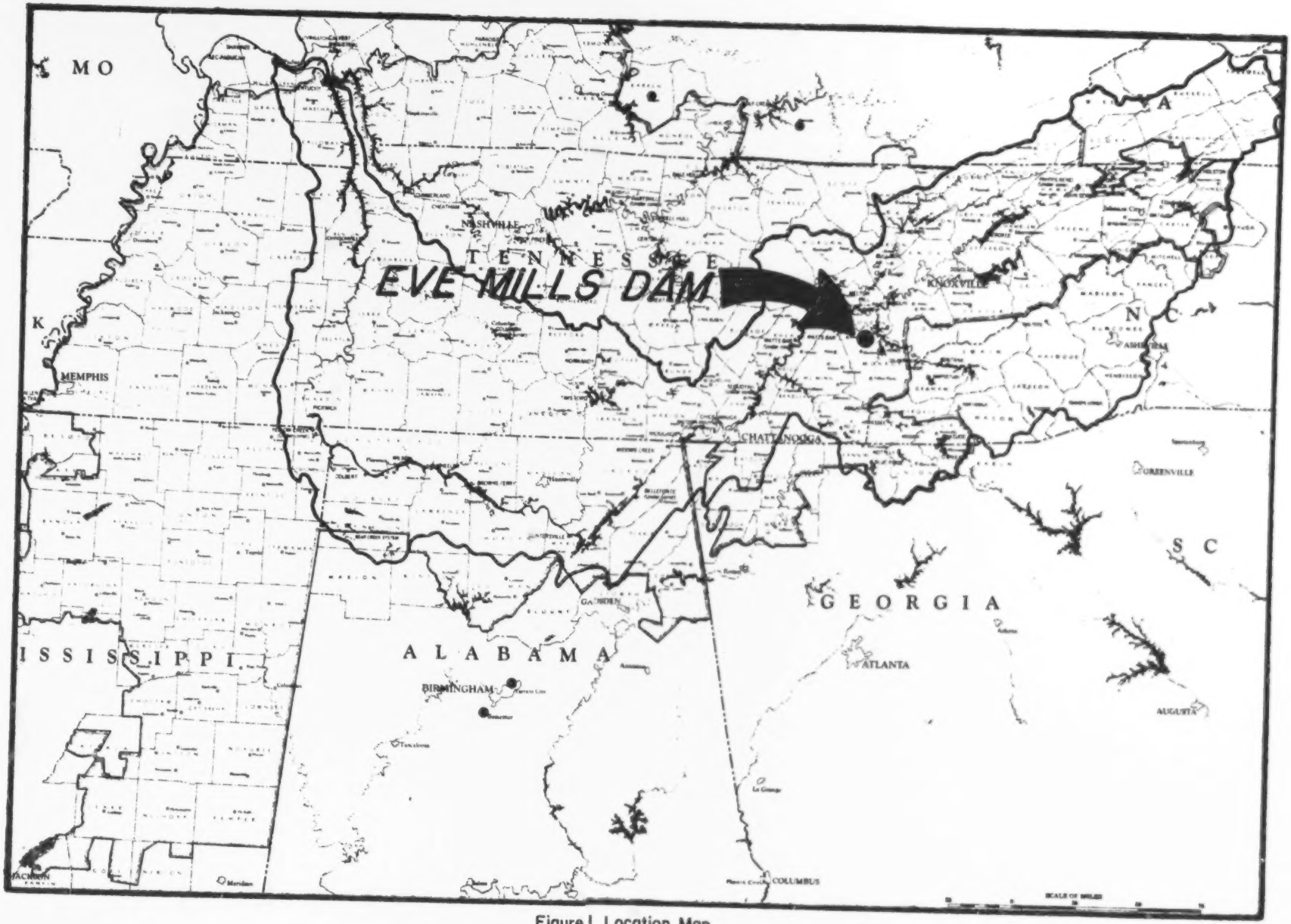

Figure I. Location Map

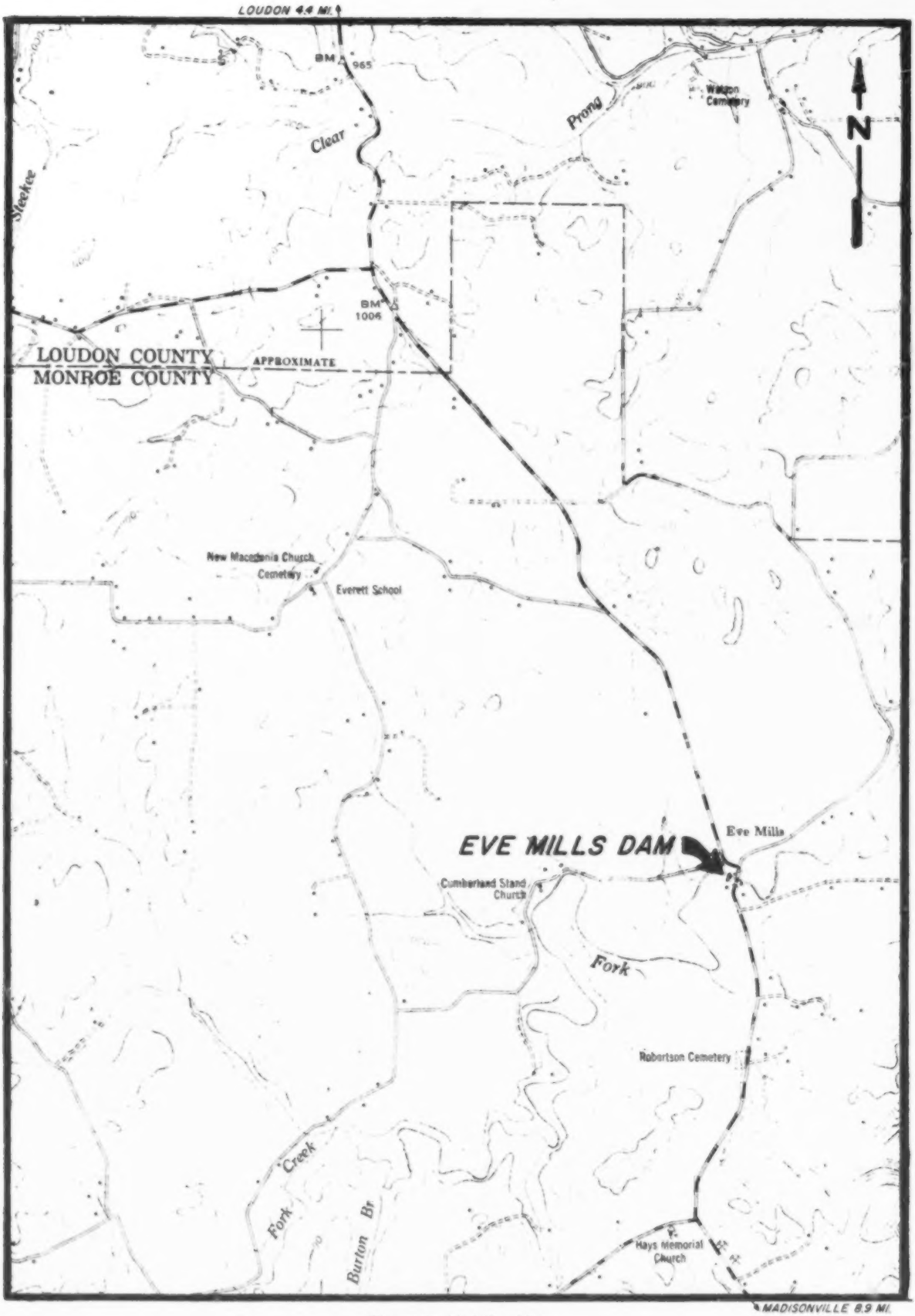

Figure 2. Vicinity Map

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C. Turbine

The turbine at Eve Mills is located in an open concrete flume on the left abutment of the dam. The turbine was purchased second hand and installed when the dam and flume were constructed in the late 1940's. Its age and original installation are unknown, but field inspection indicates that it is a size 35 Samson turbine manufactured by The James Leffel and Company of Springfield, Ohio. Under a ten-foot head a new size 35 Samson turbine develops about 78 horsepower at full gate. The turbine was overhauled by local labor when it was installed at Eve Mills. The turbine presently operates a small grist mill through a quarter turn belt and two line shafts and is controlled manually by a handwheel in the building. The turbine appears to be in good condition and runs smoothly without excessive noise or vibration.

D. Water Conductors

The flume and turbine pit are reinforced concrete founded on limestone bedrock. At the entrance to the flume there is a stop log groove for dewatering the flume and a rudimentary trashrack. Water is discharged from the turbine about fifty feet downstream of the dam. The flume and turbine pit are in good condition. Directly above the flume and turbine pit there is an open shed approximately twenty by sixty feet which provides access to the turbine and the dam.

E. Dam

The dam consists of two types of construction: limestone masonry and concrete. The masonry abutments predate the concrete spillway section and were originally tied to a timber spillway section.

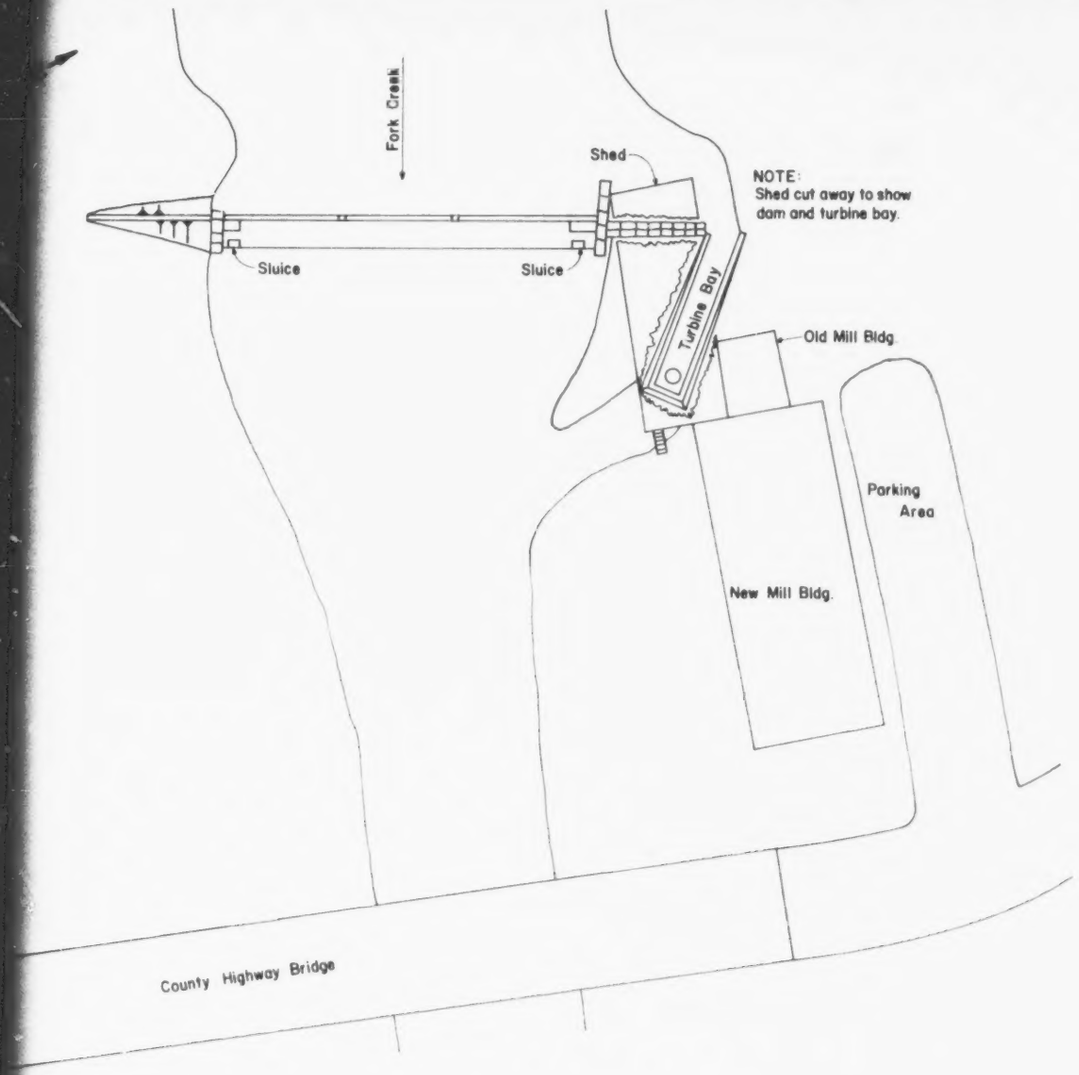
Aside from minor leaks the masonry is in good condition. The spillway is a trapezoidal concrete gravity section 91 feet long and 10 feet high founded on bedrock. A brief stability analysis indicated the structure to be safe from failure by overturning or sliding. Two sluices which were last operated in 1979 allow the reservoir to be drawn. There is some leakage amounting to not more than two cfs through the slabby limestone on both banks.

The mill pond extends about seven hundred feet upstream from the dam and has a volume less than 15 acre-feet. Little silt has accumulated behind the dam.

IV. HYDROLOGY AND HYDRAULICS

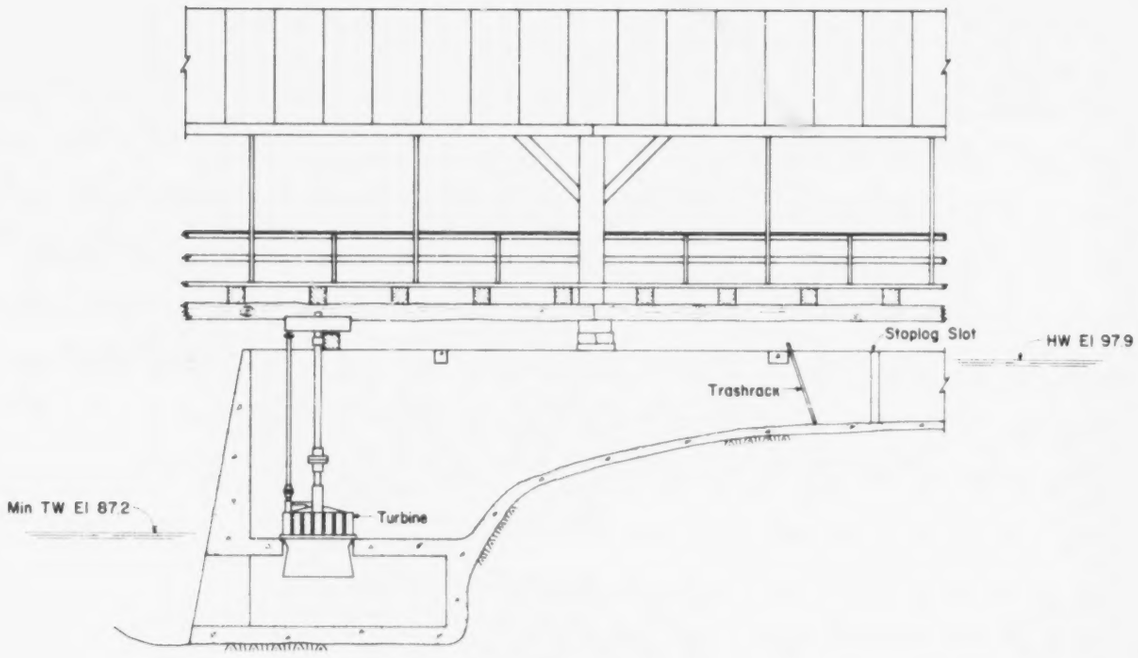
Fork Creek at Eve Mills Dam drains a 31.8 square mile watershed devoted primarily to agricultural use. Annual precipitation in the area averages approximately 52 inches. Based on records available for nearby gages the average annual flow at Eve Mills is 54 cfs and the seven-day, ten-year low flow is about 10 cfs.

Since there are no historical records of streamflow for Fork Creek, streamflow records from a nearby basin with similar characteristics were adjusted on the basis of relative drainage areas to generate a representative flow duration curve. The Oostanaula Creek watershed borders on the Fork Creek watershed and has streamflow records from 1954 to the present. At the USGS gage near Sanford, Tennessee, Oostanaula Creek has a drainage area of 57.0 square miles. Figure 4 is the adjusted duration of flow curve for Fork Creek at Eve Mills based on a drainage area ratio of 31.8 to 57.0 square miles.



PLAN

Scale 20 0 20 40 Feet



SECTION THRU TURBINE BAY

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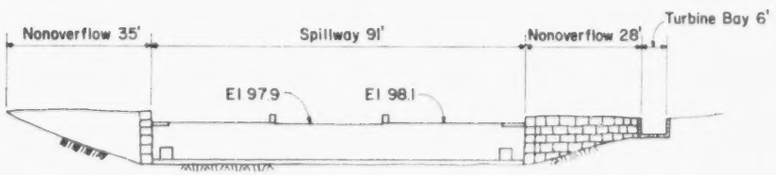

DOWNSTREAM ELEVATION

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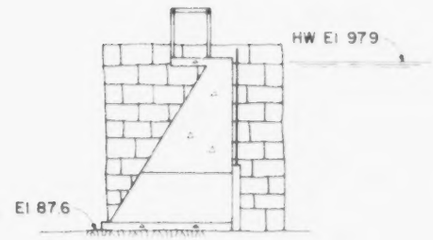

SECTION THRU SLUICE

Scale 5 0 5 10 Feet

NOTE
Elevations based on arbitrary datum
elevation 1000

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Figure 3 Existing Facilities-Eve Mills Dam

Flood frequencies for Fork Creek at Eve Mills were determined using the annual peak flows from the Bat Creek watershed which is adjacent to Fork Creek and has virtually the same drainage area. Based on the period from 1955 to 1976, the 100 year flood on Bat Creek is approximately 6600 cfs. Two flows approaching this value have occurred in the period of record: 5060 cfs in 1963 and 4400 cfs in 1973. According to the mill operator the 1973 flood crested just beneath the floor of the mill. Large flows such as in 1963 and 1973 pass over the entire length of the dam including the abutments and there is little difference in the headwater and tailwater elevations. The 100-year flood would flood the existing mill. Failure of the dam would pose little or no downstream hazard.

V. PROJECT DEVELOPMENT

The usual procedure in hydroelectric development studies is to select several capacities and configurations and to then study each in sufficient detail to determine the optimal design. However, at Eve Mills the development alternatives are limited to the use of the existing turbine because of the high cost of a new turbine relative to the small power potential of the site. Assuming the use of the existing turbine, alternative developments include various types of generators, drive trains, and headwater control devices.

Either a synchronous or induction generator could be installed at Eve Mills, but there are advantages to the induction type. Since it is difficult to parallel a small synchronous generator with the power grid, there would be no market for the power produced by a synchronous machine other than the mill requirements which are very slight. Also, the

synchronous machine would require an expensive speed regulating governor to maintain frequency and voltage. Since an induction generator takes its frequency and voltage regulation from the power grid, a governor is unnecessary. For these reasons, an induction type generator was selected.

Geared and belted drive trains were considered to connect the turbine to the generator and to achieve the necessary speed increase from 145 rpm to 1800 rpm. A scheme utilizing a right angle speed increasing gearbox was considered because of its efficiency and greater reliability compared to a belt drive but was rejected because of the high cost of the increaser and because of the increased cost of supporting and protecting the equipment directly above the turbine.

The belt drive alternative which has been adopted would consist of a quarter turn belt from the turbine to the existing line shaft for the grinder and a parallel belt off the line shaft to the generator which would be located in the main building adjacent to the grinder. The approximately 20 percent loss in energy compared to a gear drive would be more than offset by the belt drive's lower cost.

A hydraulic gate controller coupled to a headwater monitor would allow semiautomatic operation. The controller would match the flow through the turbine to the available streamflow and also would close the turbine gates in the event of overspeed or other emergency. Manual operation would be possible and would be less expensive, but was rejected because of possible damage to the equipment in the event of an emergency when the plant was unattended. Manual operation would also require greater attention and would result in less efficient use of water.

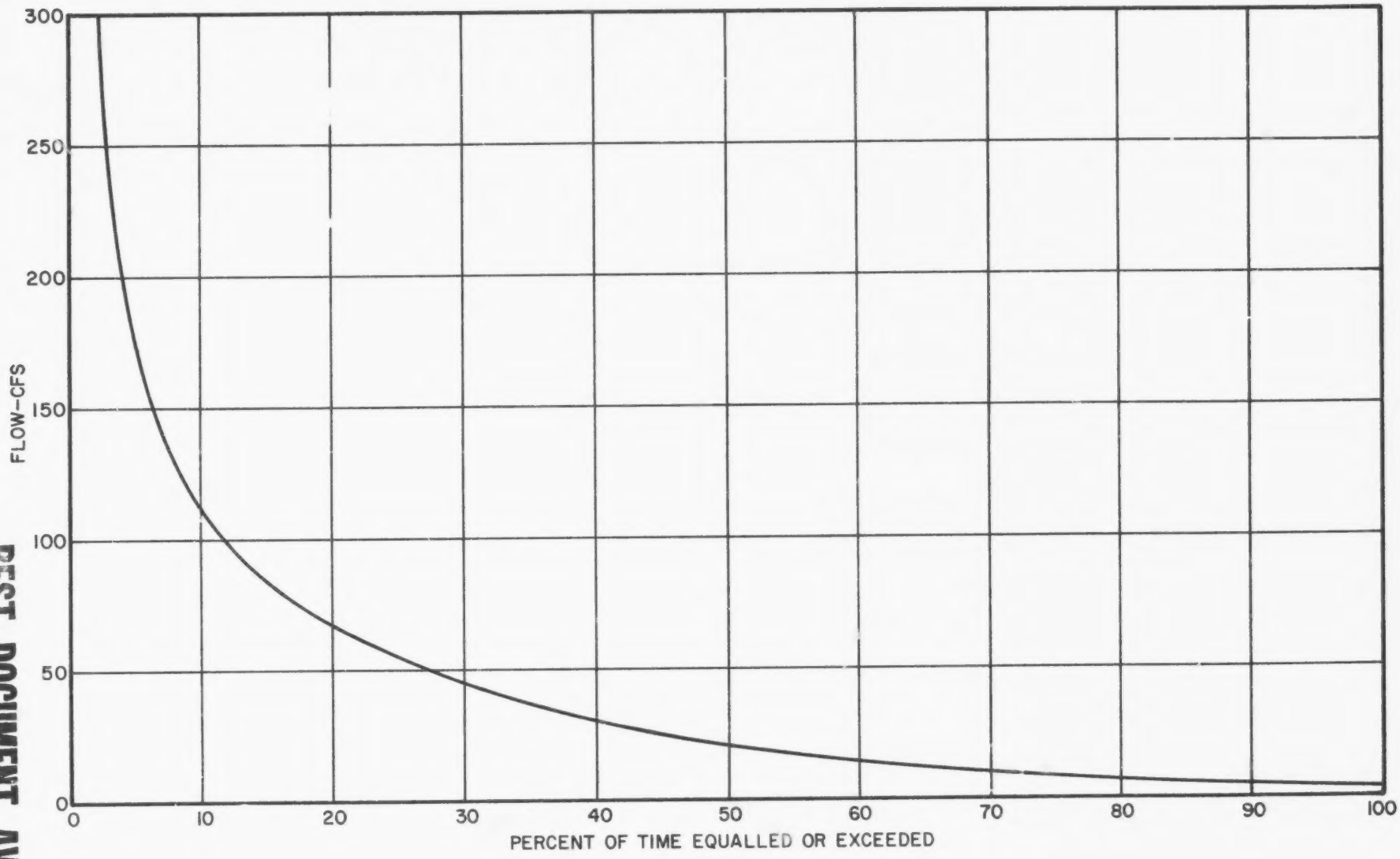

Figure 4. Duration of Flow

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VI. POWER PRODUCTION

Since the storage in the mill pond is very limited, operation was assumed to be run-of-river. The average annual power production at Eve Mills was estimated by converting the usable flow under the flow duration curve into an energy value using an average net head and variable equipment efficiencies. Usable flows range from 36 cfs to 82 cfs. The net average head was developed using an average tailwater condition and conservatively high energy losses in the trashrack and forebay. The James Leffel and Company supplied turbine efficiencies for a size 35 Samson turbine operating under the average head and varying flows. These efficiencies were reduced since the turbine at Eve Mills is old and has been repaired. Overall efficiency was further reduced to reflect energy losses in the speed increaser and generator.

The average annual generation at Eve Mills was estimated to be 100,000 kWh and full gate output would be 33 kW. For approximately 50 percent of the time, flow conditions would not be suitable for plant operation.

VII. PROJECT COSTS

The project cost in 1981 dollars of adding electrical generating facilities to Eve Mills Dam is estimated to be $110,000, and is comprised of estimates of equipment and structural costs, interest during construction, contingencies, and overheads. The major items in the estimate are the purchase and installation of an induction generator and accessory electric equipment. A summary of all required costs is shown in Figure 5. Opera-

tion and maintenance costs are estimated to be $2,000 per year in 1981 dollars. This assumes that the majority of the operation and maintenance duties would be performed by the developer.

It should be recognized that these costs are based on TVA's experience on similar work at larger projects and may not be applicable to all developers. There could be some cost savings if a developer could acquire suitable used equipment, and if he could provide labor, materials, and operation and maintenance expenses at a lower cost.

VIII. PROJECT BENEFITS

Installation of generating facilities at Eve Mills would produce electricity for sale to the local distributor or TVA under TVA's Dispersed Power Production Policy which encourages energy production from renewable sources as called for by the Public Utility Regulatory Policies Act of 1978 (PURPA). The program's rates, which are based on the wholesale power rates which TVA charges its distributors, are used to evaluate energy production.

Under the program's present rate structure for plants having less than 100 kW capacity, electricity is worth 3.325 cents per kWh. Using this value, the average annual energy production of 100,000 kWh is worth approximately $3,300.

IX. ECONOMIC ANALYSIS

The feasibility of adding hydroelectric generating facilities to Eve Mills Dam was evaluated by comparing the present worth of the

EVE MILLS DAM

HYDROELECTRIC PLANT INSTALLATION

Estimate of Cost[1]

Powerhouse	$ 1,000
Intake	1,000
Water Conductors	1,000
Turbine-Generator Equipment	16,000
Electrical Equipment	42,000
Construction Facilities	8,000
Total Direct Construction	69,000
Field General Expense	5,000
Contingency	15,000
Total Field Construction	89,000
Interest During Construction	6,000
Total Construction	95,000
Engineering Design	10,000
Administration	5,000
Total Project	$110,000

[1]Total project cost is based on 1981 dollars. This estimate does not include the primary reclosure or the 13.2 kV to 480 V transformer.

Figure 5: Cost Estimate

project's benefits and costs over an assumed 35-year economic life of the project to form a Benefit-Cost (B/C) ratio. Benefits are based entirely on the amount of energy supplied to the local transmission system. Project costs are comprised of the capital cost of the rehabilitation work and the present worth of operation and maintenance costs. A discount rate of 15 percent, which is the approximate current prime rate, was assumed since the most likely developer would be a private investor.

The present worth of power benefits and operation and maintenance costs was computed for two different economic forecasts. An escalation rate of 10.5 percent was assumed for the first eleven years in the high forecast and 10.0 percent for the remainder of the economic life. In the low forecast 7.3 percent escalation was assumed for the first 11 years, 5.5 percent for the next 8 years, and 6.0 percent for the last 16 years.

The present worth of the project benefits and costs for the high forecast equals $54,000 and $143,000, respectively, resulting in a B/C ratio of 0.38. The low forecast present worth values for project benefits and costs are $37,000 and $132,000, respectively, which yield a B/C ratio of 0.28. Therefore, project implementation would not be favorable based on the assumptions used for these calculations. However, it is emphasized again that the assumptions made in this analysis do not necessarily apply to each developer.

Figure 6 shows the sensitivity of the B/C ratio to varying discount and escalation rates assuming a 35-year economic life. The B/C ratio can be significantly affected by a different prediction of the future state of the economy, a different applicable discount rate, and reduction in the total project cost.

X. ENVIRONMENTAL ASSESSMENT

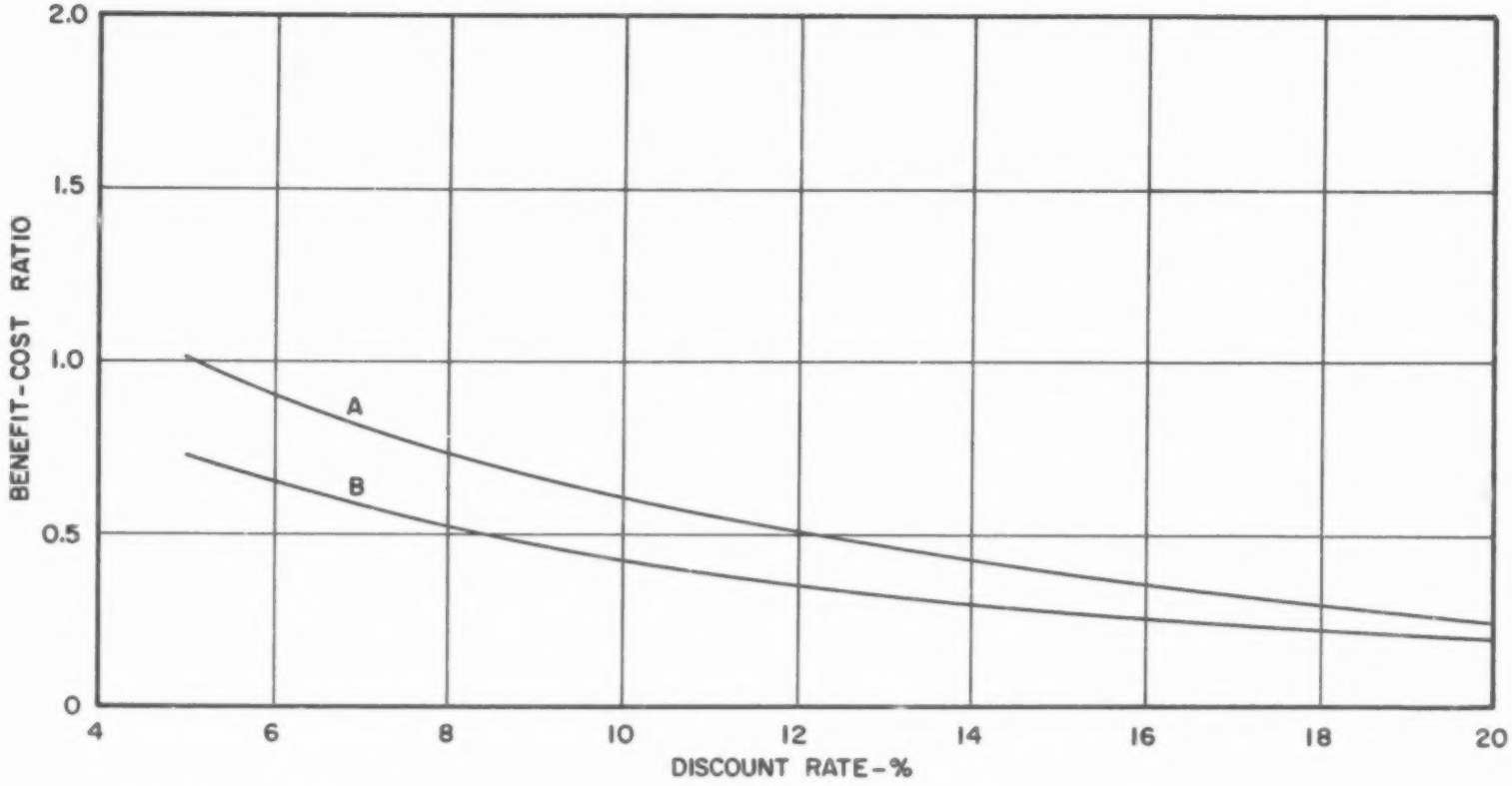
Since the development of generating facilities at Eve Mills Dam would entail virtually no change in either the streamflow regime or the existing facilities, the environmental impact would not be significant. This statement is supported by proposals by the Federal Energy Regulatory Commission (FERC) to exempt projects such as Eve Mills Dam from licensing as provided in Part I of the Federal Power Act. Their reasoning is that projects of such small size would cause only a minimal impact on the environment.

XI. CONCLUSIONS AND RECOMMENDATIONS

Based on the analysis made in this study, adding hydroelectric power generating facilities to Eve Mills Dam is not presently economically feasible. Depending upon the economic forecast assumed, the Benefit-Cost ratio ranges between 0.28 and 0.38 at a 15 percent discount rate.

As mentioned in previous sections, assumptions made in this analysis may or may not apply to a potential developer. The total project cost is based on TVA costs and accounting procedures, and could be reduced if the developer could obtain suitable used equipment, provide labor, materials, and operation and maintenance expenses at a lower cost, and reduce overhead costs. In the case of Eve Mills Dam, being a relatively small installation, the developer should be able to perform much of the construction work himself as well as operate and maintain the plant.

From a financial standpoint, the developer should be aware that there could be negative cash flows for the first several years of operation



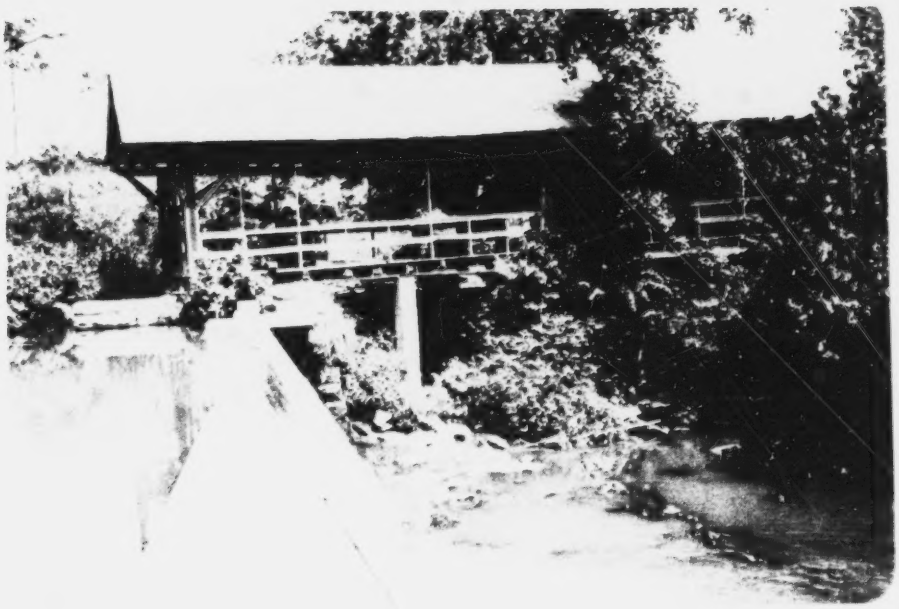
LEGEND:
A-High escalation rate for benefits and O&M costs
B-Low escalation rate for benefits and O&M costs

Figure 6. Discount Rate vs Benefit-Cost Ratio

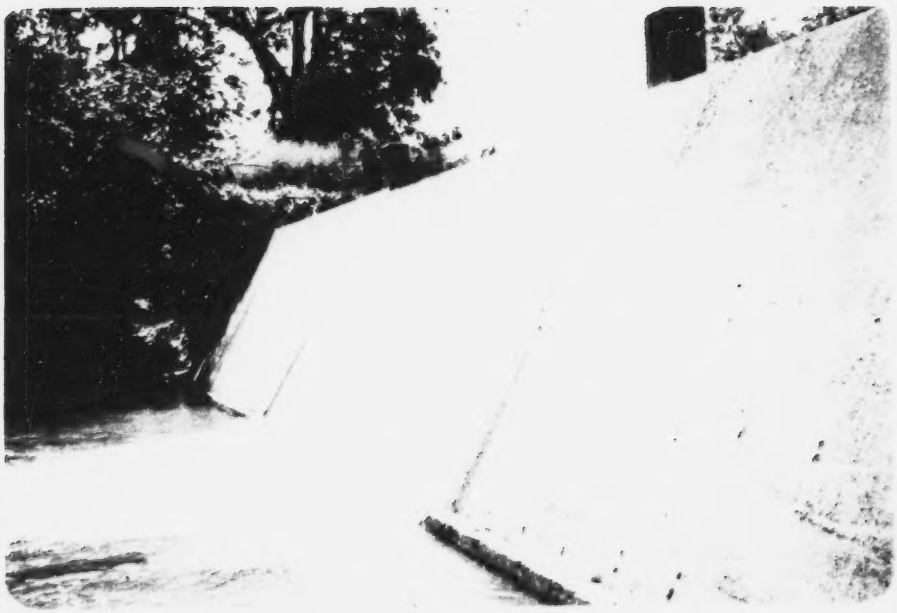
until escalating benefits reach and surpass costs. On the positive side, there are several tax incentives available to a small hydro investor which might make the project more attractive.

Several regulations apply to small hydro projects. The developer must be prepared to obtain the required licenses and permits to construct and operate the project from the appropriate organizations on the local, state, and Federal levels of government. Some agencies which do not require a permit or license must be contacted for comment.

A developer interested in developing this site in light of the above problems and requirements should make an analysis based on his individual financial situation to determine whether or not to proceed with redevelopment.



View of sawmill shed



Downstream view of dam

APPENDIX E

McMinnville DAM

APPENDIX E

FEASIBILITY REPORT - MCMINNVILLE DAM

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SUMMARY OF PRINCIPAL FEATURES

McMinnville Dam

Location
On the Barren Fork River at mile 6.3, in Warren County, Tennessee.

Owner
City of McMinnville

Streamflow	
Drainage area	297 sq. miles
Average discharge	475 cfs
Tailwater	
Normal operating	El. 867.8
Minimum	El. 867.4
Operating Heads (net)	
Maximum	14.4 ft
Minimum	4.2 ft
Rated	12.5 ft
Dam	
Type	concrete gravity and timber crib overlain with concrete
Length	320 ft
Height	20 ft
Top of spillway	El. 881.9
Possible Power Facilities	
Existing intake channel	75 ft open flume
Existing powerhouse	20 ft x 20 ft reinforced concrete
Hydraulic turbines	
Number	one
Type	Francis, vertical shaft, open flume
Runner diameter	36 in
Generator	
Type	induction, vertical shaft
Rating	225 kW
Plant output:	
Average annual energy	1,400,000 kWh
Cost	
Total project cost	$900,000
Cost per kW	$4,000

SUMMARY

This report presents the results of a study to determine the feasibility of restoring the hydroelectric generating facilities at McMinnville Dam. The costs used for this report reflect construction costs experienced by TVA including overheads normally used in TVA accounting procedures and may or may not apply to a developer.

The evaluation of several alternative plans using TVA costs and benefits and an assumed discount rate indicates that the redevelopment of McMinnville Dam could be economically feasible to a developer whose financial situation is suitable. A detailed financial analysis would be required by a developer for him to reach a final decision on project implementation.

I. INTRODUCTION

The purpose of this report is to investigate the possibility of restoring hydroelectric power generation facilities at the McMinnville Dam on the Barren Fork River in Warren County, Tennessee.

This report is part of the second phase of TVA's Small Hydro Program which was begun in 1979 to investigate the potential for small scale hydroelectric production in the Tennessee Valley region. The first phase, which was completed in June 1980, consists of an inventory and screening of existing non-Federal dams in the Tennessee Valley and the TVA power service area. The second phase consists of more detailed feasibility studies on ten of the most promising sites based on the results of the reconnaissance phase.

Included in the feasibility analysis for McMinnville Dam is a detailed cost estimate, evaluation of project benefits, and computation of a Benefit-Cost ratio. A potential developer can use these to help make a decision regarding whether or not to proceed with rehabilitation of the facility.

II. SITE HISTORY

A dam has existed at the present McMinnville Dam site since before the Civil War. The present dam has been raised and modified through the years with a major reconstruction in 1929 when the right section of the dam, after being washed away by the largest flood on record, was replaced by a new concrete section.

The first hydroelectric generating unit was installed in the Falcon Flour Mill on the right bank in 1907 by Mr. J. Walling. This plant operated only a few months until a new powerhouse equipped with a 200 kW horizontal generator was built on the opposite side of the river. This facility was operated until 1923 when it was then replaced by the present hydroplant. The new installation housed a Leffel Francis-type turbine rated at 380 hp and 164 rpm which was connected to a 250 kW generator manufactured by General Electric. Operation of the plant was classified as semi-automatic.

Ownership of the facility changed hands in 1926 when the Tennessee Electric Power Company bought Mr. Walling's interest. The Tennessee Valley Authority acquired the project in 1939 and sold it to the City of McMinnville after retiring the hydroplant in 1949.

In its final years the generating station was used primarily for voltage regulation and an emergency supply for the McMinnville area.

III. SITE DESCRIPTION

A. General

McMinnville Dam is located in McMinnville, Tennessee, on the Barren Fork River at river mile 6.3 in Warren County (see Figures 1 and 2). The major features of the project consist of a dam, and an intake channel and powerhouse on the left bank (see Figure 3). Access to both sides of the dam is via unimproved roads off State Highway 108 which crosses the river approximately 300 feet downstream of the dam. An L&N railroad bridge crosses the reservoir just upstream.

Currently the major purpose of the reservoir is water supply for the McMinnville area. Intakes for the water treatment plant are located on

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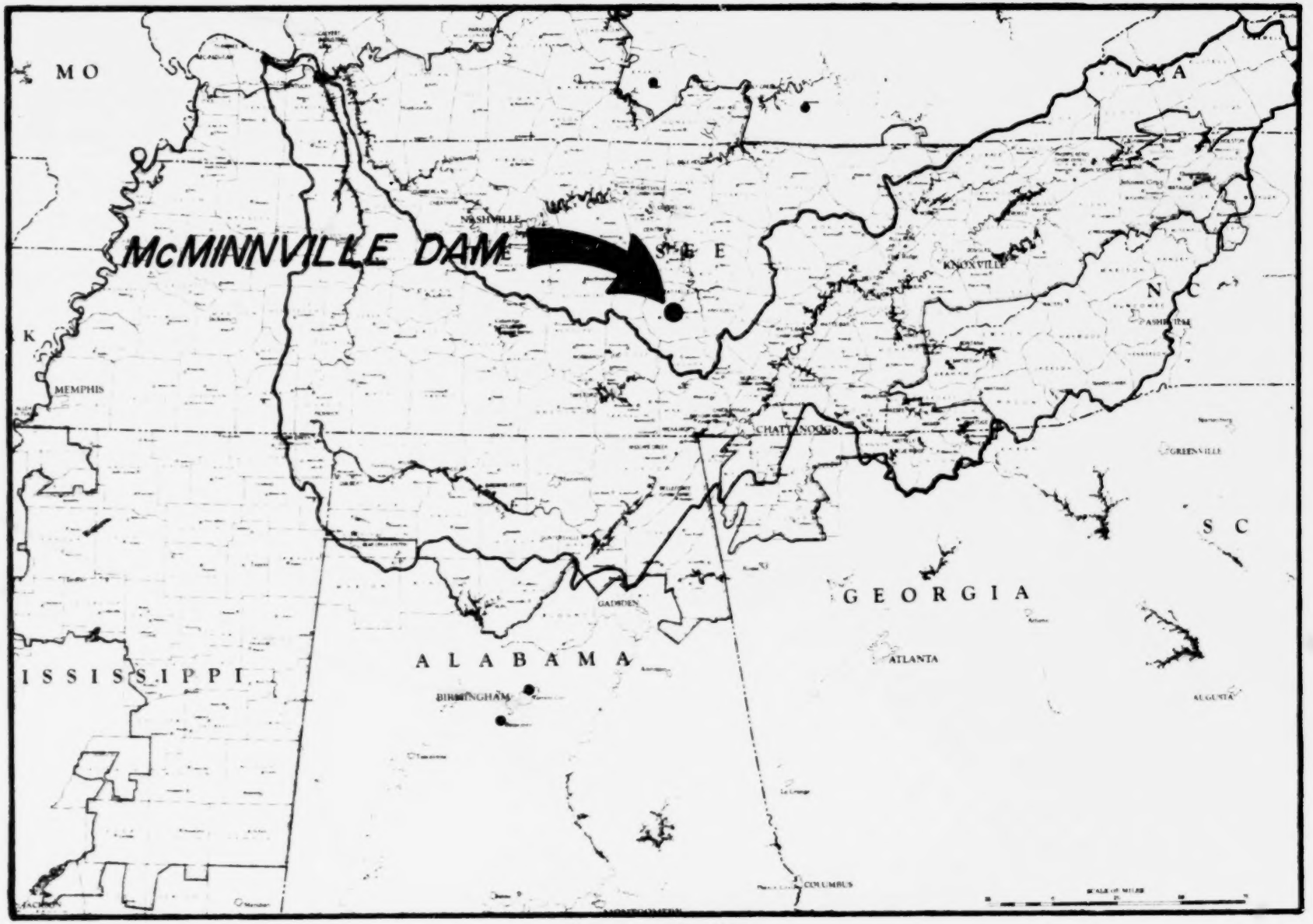

Figure I. Location Map

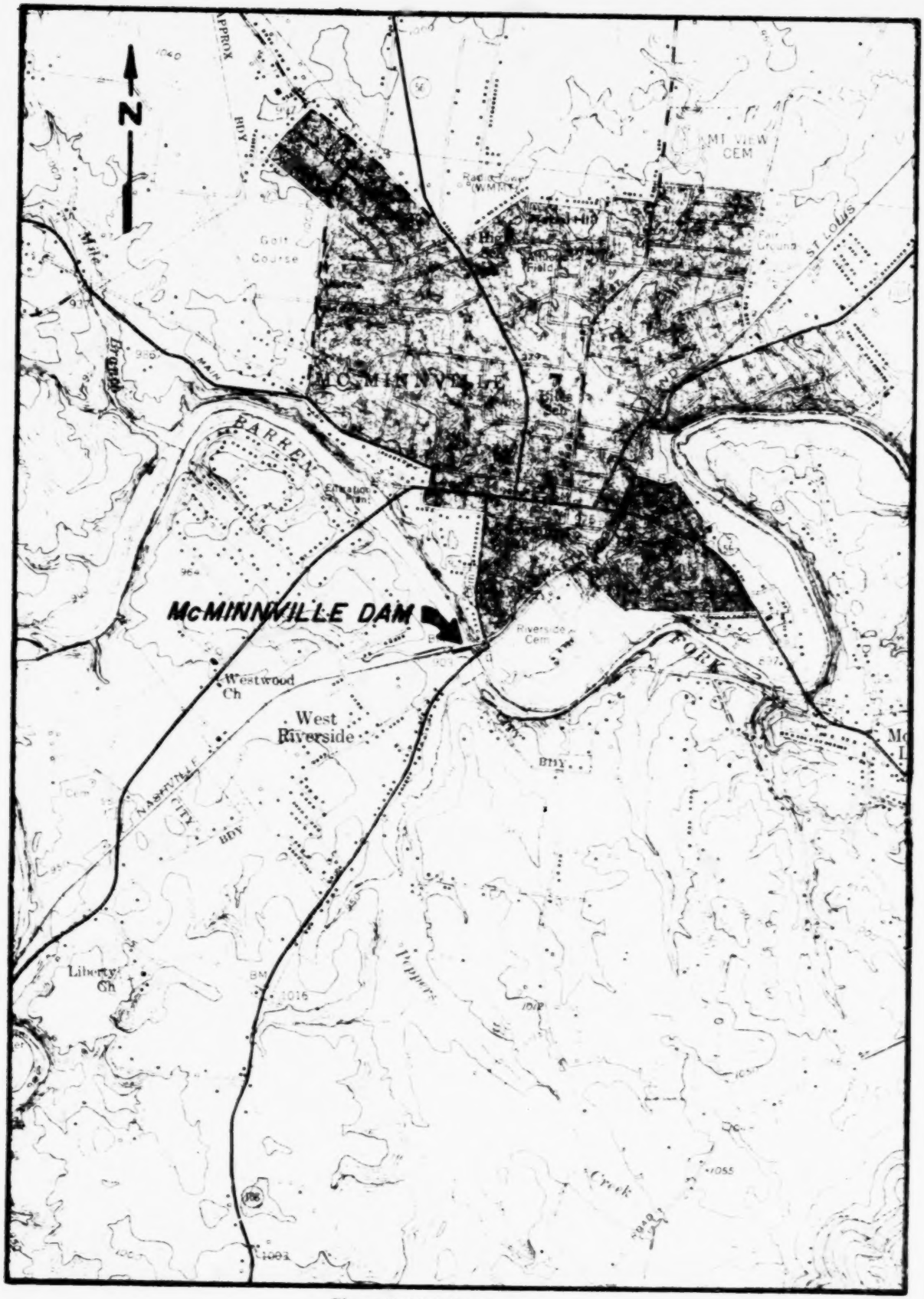

Figure 2. Vicinity Map

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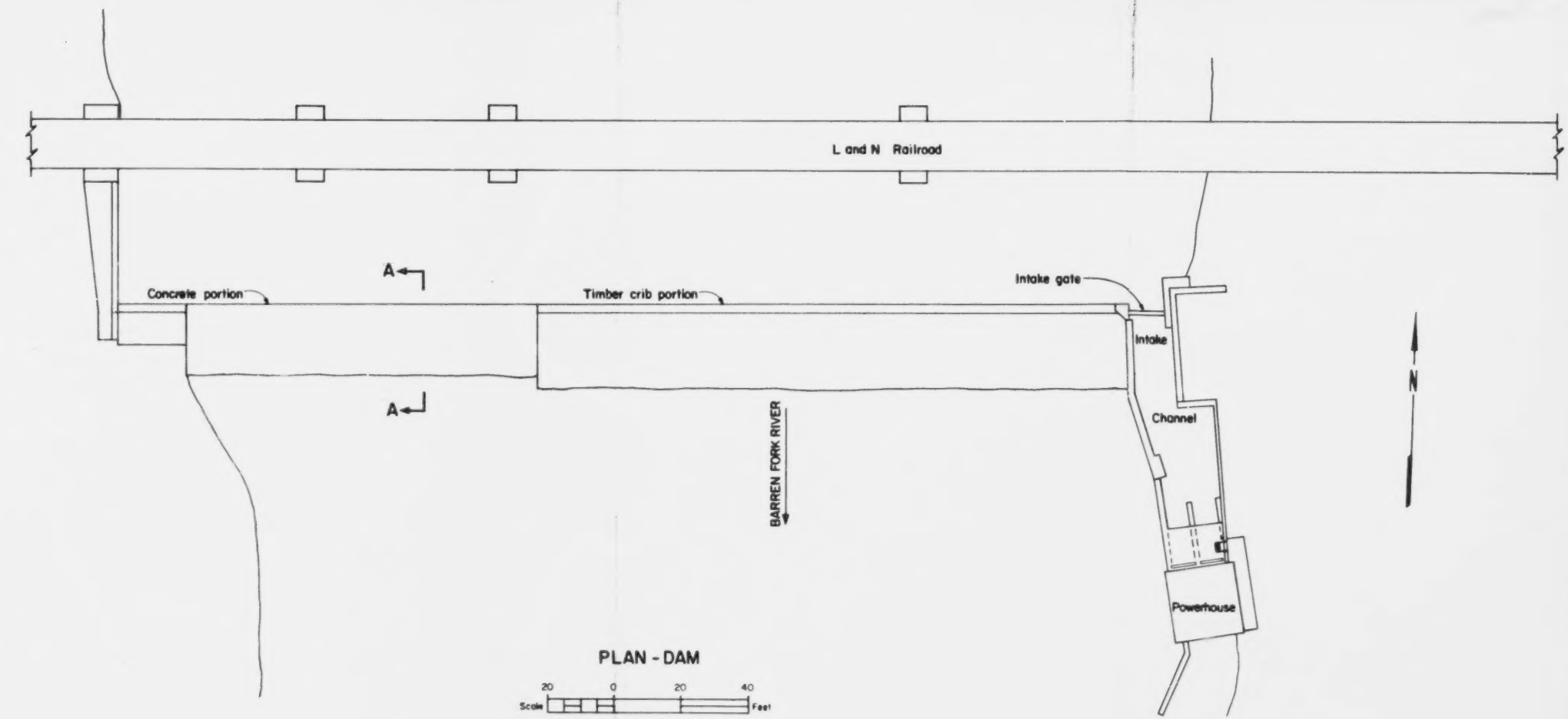
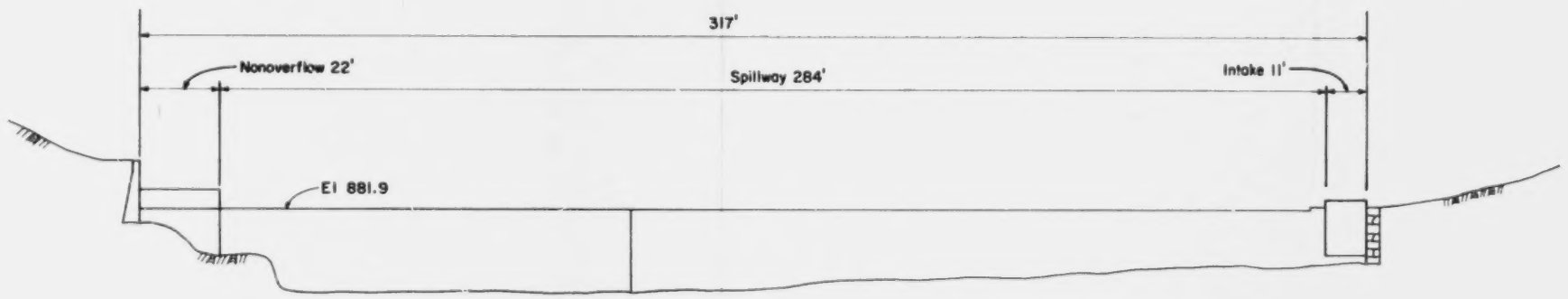


PLAN - DAM

Scale 20 0 20 40 Feet



DOWNSTREAM ELEVATION

Scale 20 0 20 40 Feet

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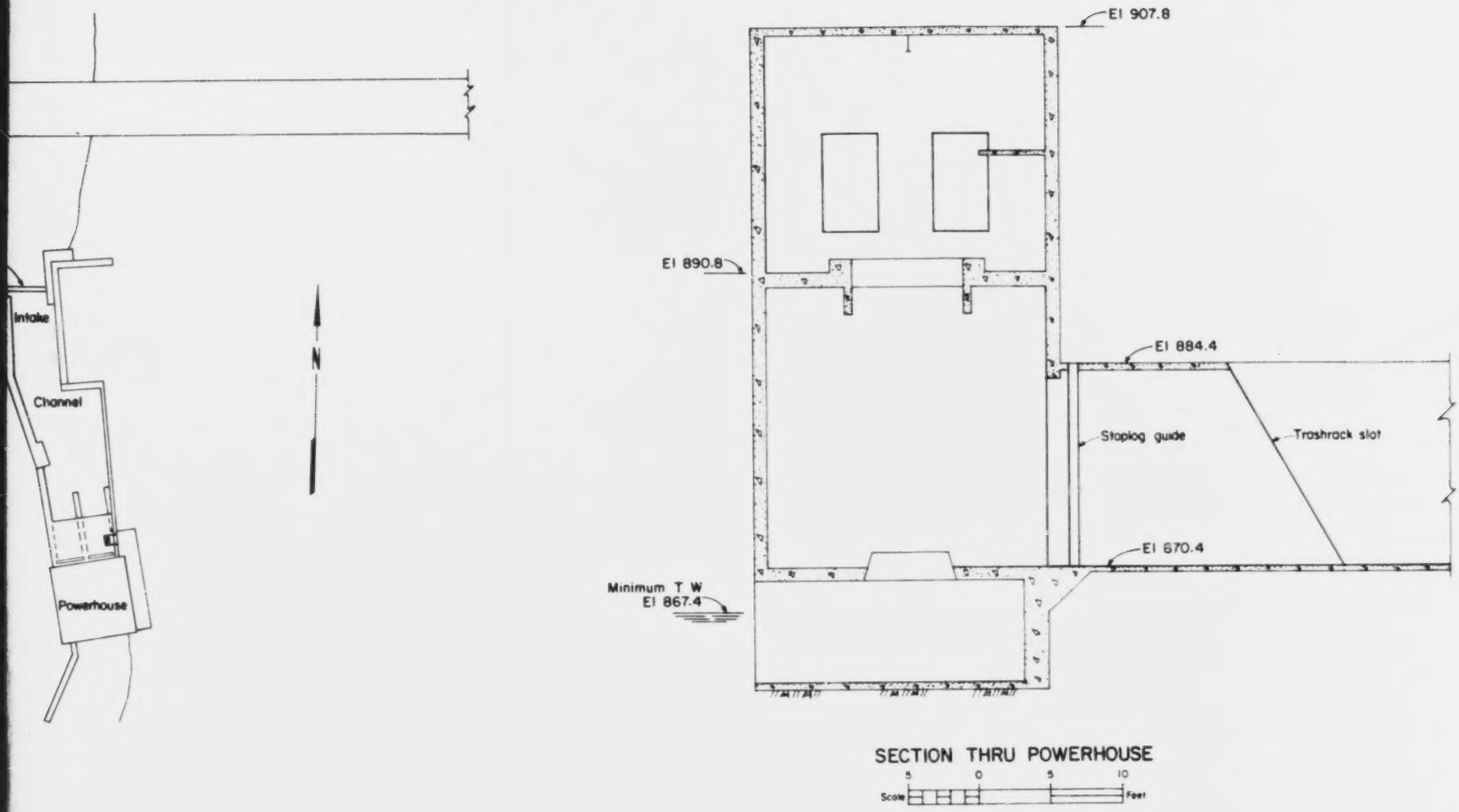

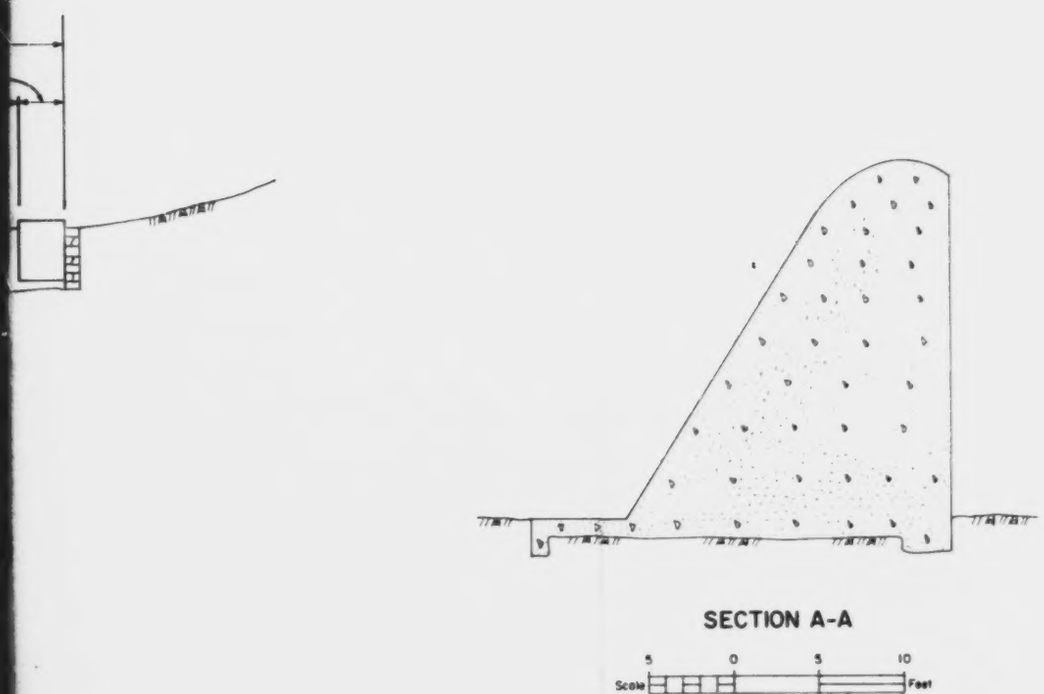

Figure 3. Existing Facilities-McMinnville Dam 81A

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the right bank near the dam. Withdrawal averages 3.5 to 5.0 million gallons per day with a planned ultimate demand of 7.5 million gallons per day. The area downstream of the dam is used by local fishermen.

B. Dam

The dam is approximately 320 feet in total length and 20 feet high. The left section of the dam is the original rock-filled timber crib structure which has been covered with concrete and strengthened by the addition of concrete at the toe. The crest is three feet wide and the face is very rough and covered by small vegetational growth. Deterioration is especially severe at each end of this section, and some leakage from underneath occurs throughout. The right section of the dam is an ogee shaped concrete gravity structure which ties in to a railroad support at the right abutment. No problems are evident at this section.

C. Intake Channel

An intake channel is located at the left bank which conveyed water approximately 75 feet downstream from the dam to the powerhouse. The walls and floor are concrete except for the upper half of the wall nearest the bank which is formed by the limestone block foundation of an old building. A steel slide gate is in place at the channel entrance, and a wooden slide gate, used for dewatering purposes, is located on the wall nearest the river. A trashrack structure minus the steel trashracks is situated about 12 feet from the powerhouse with two empty slots for stop logs at the powerhouse. A lifting mechanism for the sluice gate is in place. The channel has deteriorated over the years with trees and other smaller vegetation readily growing in the floor and wall nearest the bank.

A large hole is present where the dam joins the channel wall. Water which leaks into the channel near the entrance disappears through the floor.

D. Powerhouse

The powerhouse is a concrete structure in relatively good condition with three floors. The turbine sat on the second floor and discharged water into the lower level which directed the flow into the tailrace. The upper floor contained the generator, governor, controls, and all electrical equipment. The doors and glass in the windows are missing, and essentially all the generating equipment has been removed. The steel draft tube is still in place.

E. Tailrace

The tailrace is located immediately downstream of the powerhouse and is parallel to the river. The tailrace channel is approximately 15 feet wide and is bounded by a short concrete wall on one side and the river bank on the other. Currently the channel is full of silt and debris.

F. Substation and Transmission Lines

A small substation which was used by the hydroplant is located on a hill approximately 200 feet east of the powerhouse. The Maloney transformers are still in place. Some small transmission lines radiate from the substation, and other lines cross the river at the railroad bridge, State Highway 108 bridge, and over the powerhouse. The McMinnville-Morrison 161-KV line passes 1½ miles from the dam.

IV. HYDROLOGY AND HYDRAULICS

Land drained by the Barren Fork River is largely agricultural in use and totals 297 square miles at McMinnville Dam. A small reservoir with no appreciable storage capacity is impounded by the dam and is primarily used for the city of McMinnville's water supply. Withdrawal amounts to a small fraction of the average streamflow. Precipitation in the area averages 52 inches annually. Based on historical data from an upstream streamflow gage, the average flow at the dam is 475 cfs and the minimum flow is approximately 75 cfs. The maximum known flood occurred on March 23, 1929, and crested 17 feet above the spillway crest, which is approximately one foot below the bottom of the railroad bridge just upstream of the dam. The magnitude of this flood is similar to that of the 100-year flood. Little difference could be observed in the headwater and tailwater elevations.

A flow duration curve was generated using flows adjusted by relative drainage areas from a USGS streamflow gage on the Barren Fork River at Trousdale, Tennessee. The drainage area at this gage is 126 square miles, and records are available from 1934 through 1957. Figure 4 is the adjusted duration of flow curve for Barren Fork River at McMinnville Dam.

The 100-year flood elevation for the Barren Fork was taken from flood profiles published by the Department of Housing and Urban Development. A 100-year flood would raise the level of the river at McMinnville Dam to elevation 899 and corresponds to a flow of roughly 90,000 cfs.

V. PROJECT DEVELOPMENT

In selecting the best redevelopment plan for the project, several alternatives were considered. Emphasis was placed on minimizing civil works, selecting a standardized turbine, choosing an installation similar in size to the original unit, and ensuring that any adverse impacts on the environment be minimized.

To comply with these conditions, all alternatives would provide run-of-river operation of the hydroplant and would utilize the existing powerhouse. It was determined that the following three types of units would show the most promise of rendering a viable project:

1. Improved vertical Samson turbine manufactured by The James Leffel and Company
2. Vertical shaft TUBE turbine manufactured by Allis-Chalmers
3. Vertical Francis Type S turbine manufactured by The James Leffel and Company.

The unit selected as the best alternative for utilization at McMinnville Dam is the 36-in type S turbine. This is a Francis runner and is primarily controlled by wicket gates located at the turbine inlet (see Figure 5). The unit is designed to operate in an open flume setting which would be provided in the existing powerhouse. Placement would require modifications to the turbine and generator floors.

A vertical shaft generator rated at 225 kW would connect to the turbine through a speed increaser, and would be supported by a steel structure built on the generator floor. Power produced would be fed to nearby transmission lines.

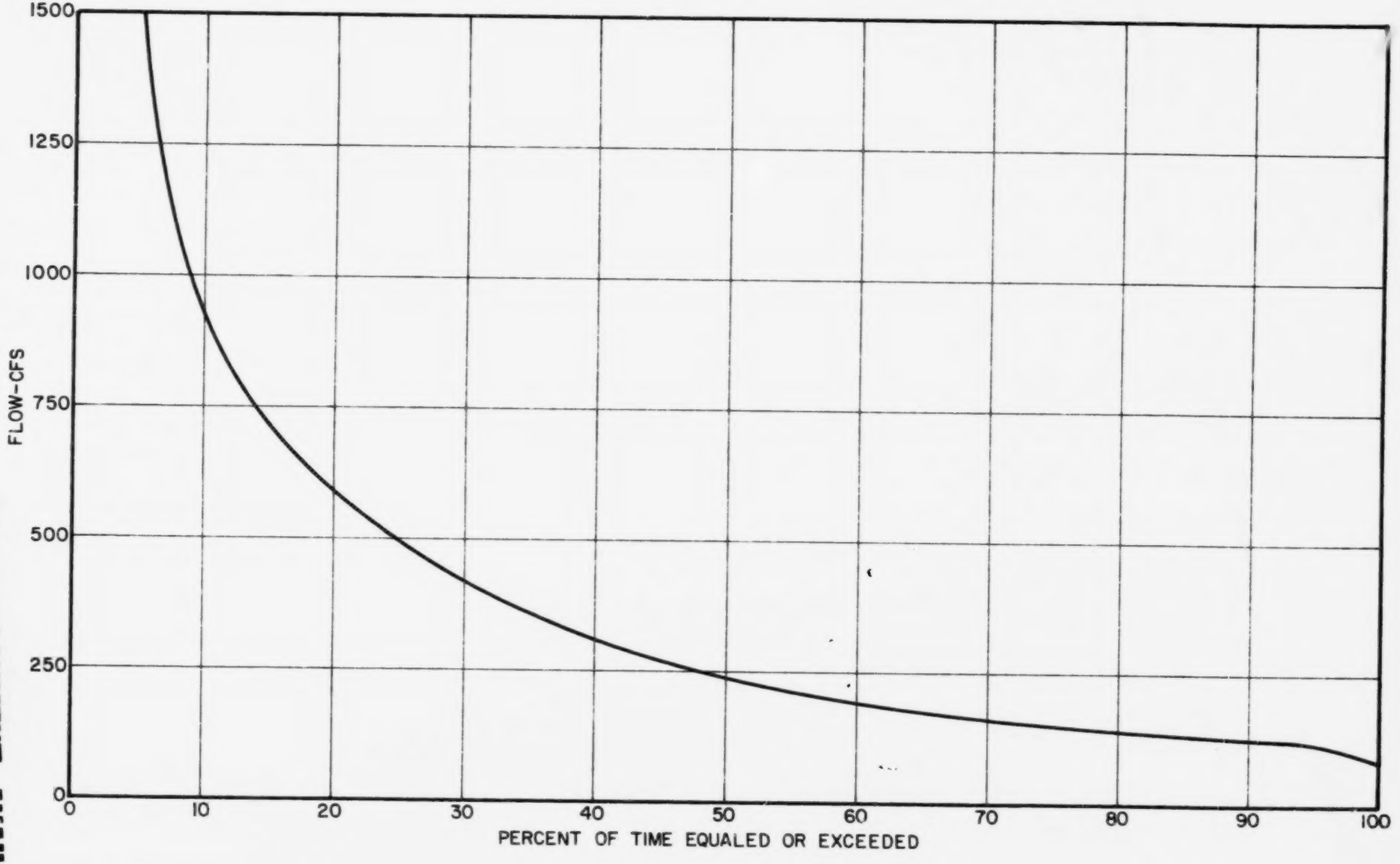

Figure 4. Duration of Flow

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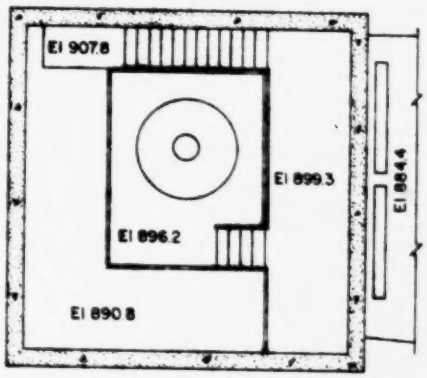
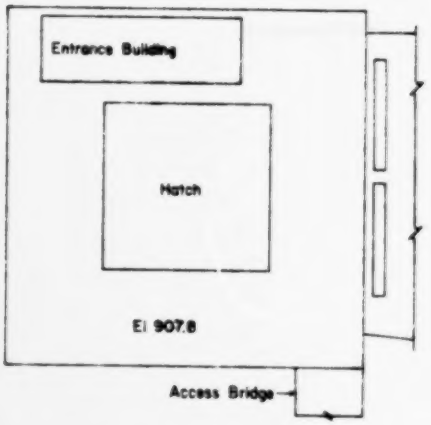
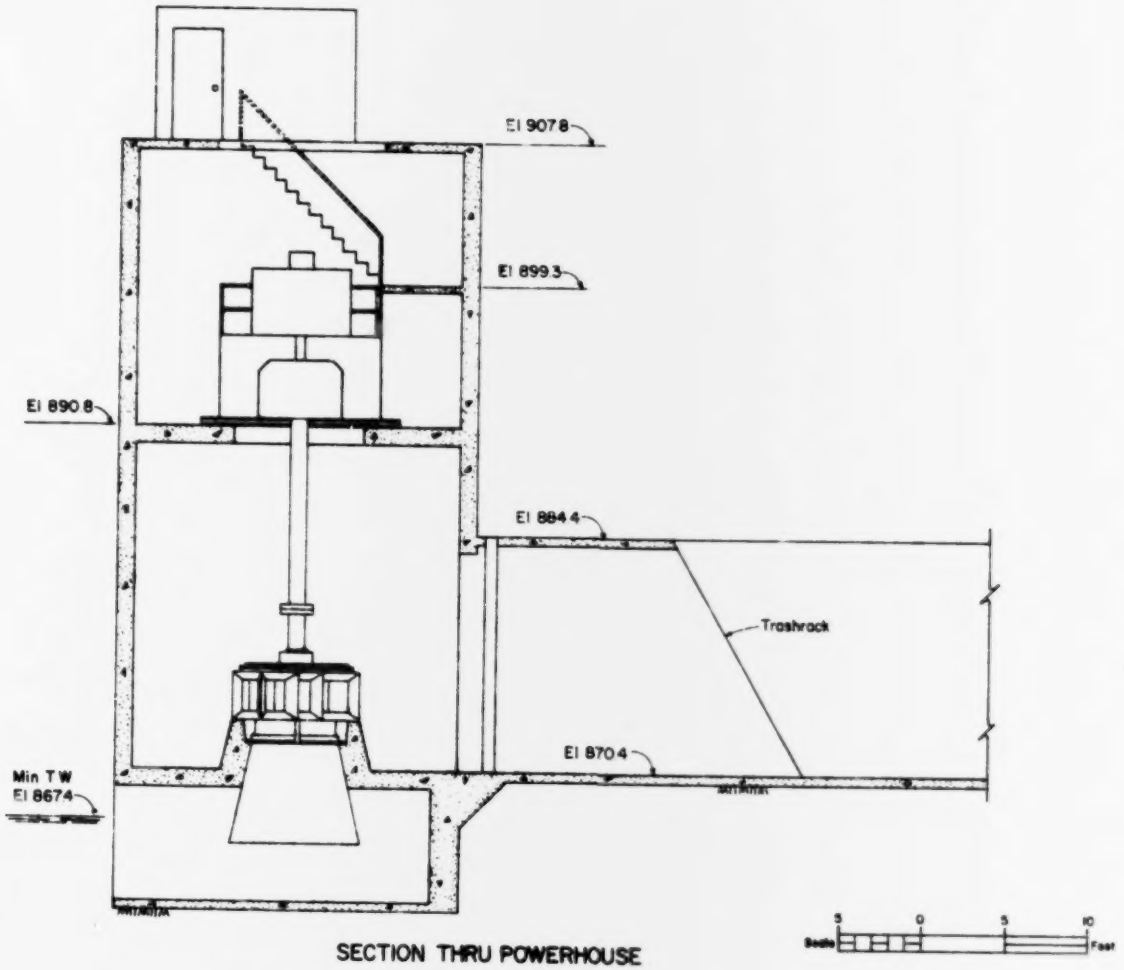


PLAN–GENERATOR FLOOR



PLAN–POWERHOUSE ROOF



SECTION THRU POWERHOUSE

Figure 5. Possible Redevelopment Plan–McMinnville Dam

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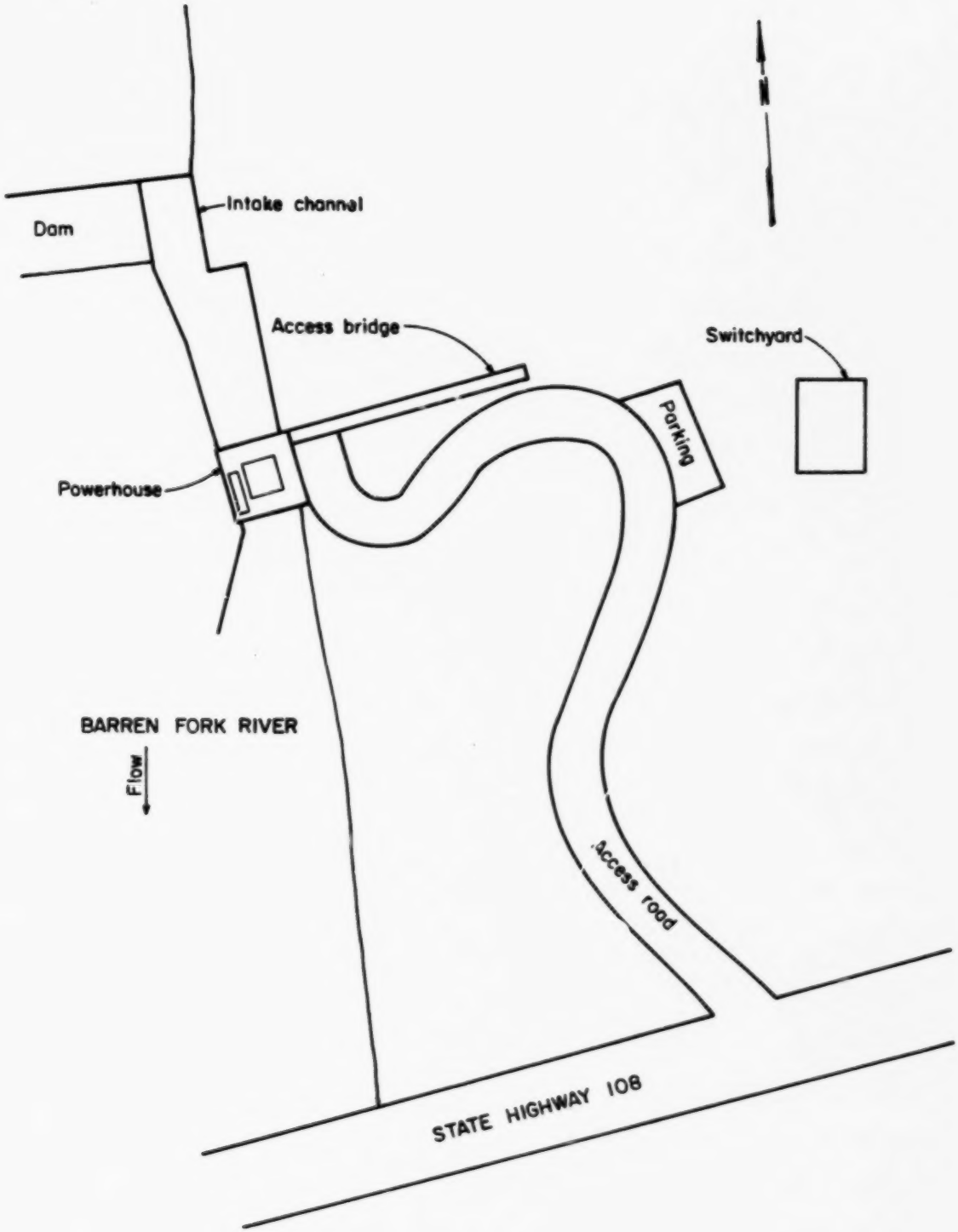

Figure 6. Possible Site Plan

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Access to the powerhouse, through the roof, would be reached by a 70-ft access bridge (see Figure 6). To protect the electrical equipment from floods smaller in magnitude than the 100-year flood, all existing doors and windows in the powerhouse would be sealed. The entrance on the roof would lead down to a reconstructed platform ten feet above the floor, from which all areas of the powerhouse could be accessed. A 10 ft x 10 ft hatch in the roof would permit placement or removal of all equipment.

Other major construction items include:

1. Repair intake channel
2. Replace trashrack and stoplogs
3. Clean out tailrace
4. Upgrade access road
5. Install necessary mechanical and electrical equipment.

Diversion and care of water would be accomplished by utilizing the existing intake and constructing a small earthfill cofferdam at the tailrace.

Normal operation of the plant would be unmanned with manual startup and automatic shutdown. Sufficient cover on the existing water supply intake would be assured by installing automatic headwater level control equipment which would limit reservoir fluctuation to less than one foot below top of dam.

VI. POWER PRODUCTION

It is assumed that operation of the possible hydroplant would be run-of-river. The potential power was determined utilizing the duration of

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flow curve shown in Figure 4. Usable flow under the curve was divided into several increments and average annual generation was computed by summing the potential energy from each increment under the curve. For this computation, a specific efficiency value was assigned to each increment of flow based on manufacturer's unit performance curves and net heads were computed using a tailwater curve and accounting for losses in the system.

Average annual energy produced by the size 36-inch S turbine unit was estimated to be 1,400,000 kWh. At full gate the unit is rated at 225 kW with an overall efficiency of 78 percent at 12.5 ft net head.

VII. PROJECT COSTS

The project cost in 1981 dollars of the most feasible redevelopment plan is $900,000, and is comprised of estimates of equipment and structural costs, interest during construction, contingencies, and overheads. The major items in the estimate are electrical and mechanical equipment, repair and alteration of the existing facilities, and site preparation. A summary of these costs is shown in Figure 7. Electrical items, contingencies, overheads, and unit costs are based on TVA costs, and the generating equipment costs were obtained from the manufacturer. Operation and maintenance costs are assumed to be $10,000 per year in 1981 dollars.

It should be pointed out that the costs presented in this estimate are conservatively high and are not necessarily applicable to all potential developers. Certain costs can be reduced depending upon the individual developer. For example, if he is willing to risk replacing or repairing all

McMINNVILLE DAM

HYDROELECTRIC PLANT REHABILITATION

Estimate of Cost[1]

General Yard Improvements	$ 11,400
Powerhouse	57,400
Intake	16,100
Water Conductors	28,100
Turbine - Generator Equipment	401,000
Electrical Equipment	53,400
Construction Facilities	70,900
Total Direct Construction	638,300
Field General Expense	44,700
Contingency	65,200
Total Field Construction	748,200
Interest During Construction	41,400
Total Construction	789,600
Engineering Design	76,600
Administration	33,800
Total Project	$900,000

[1]Total project cost is based on 1981 dollars. This estimate does not include the primary reclosure or the 13.2 kV to 480 V, 300 kVa transformer.

Figure 7: Cost Estimate

equipment damaged in the unlikely event of a very large flood, approximately $40,000 could be saved by not waterproofing the powerhouse. There could also be some cost savings if suitable used equipment could be acquired or if the developer could provide labor and materials at a lower cost.

VIII. PROJECT BENEFITS

Benefits from the possible hydro facility are based on the amount of energy made available to the local transmission system. The Public Utility Regulatory Policies Act of 1978 (PURPA) requires a utility to purchase energy offered for sale by a qualifying facility. The value of this energy is determined using the rates adopted by TVA under its Dispersed Power Production policy. The current energy price as published in the Federal Register on May 14, 1981, is 4.120 cents/kWh during peak periods, and 2.594 cents/kWh during off-peak periods. Since plant operation at McMinnville Dam would use the available inflow without regard to the time of day, the weighted average of these two rates, 3.127 cents/kWh, has been used to evaluate the energy production. Using this value, the potential average annual generation of 1,400,000 kWh at McMinnville Dam is worth approximately $44,000. The energy value is subject to change in accordance with the adjustment provisions of TVA's wholesale power contracts.

IX. ECONOMIC ANALYSIS

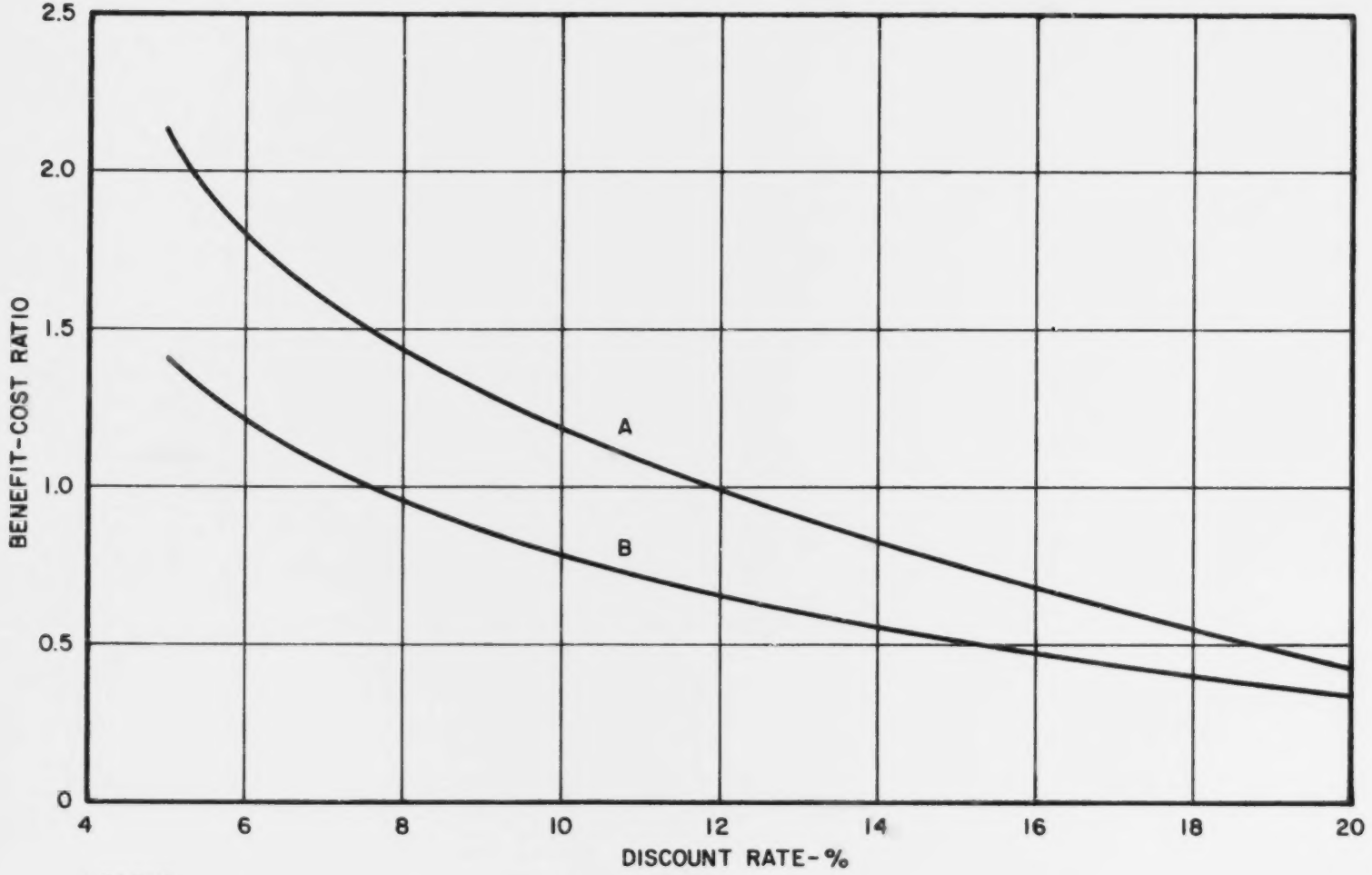
The feasibility of restoring the hydro facilities at McMinnville Dam was evaluated by comparing the present worth of the project's

benefits and costs over an assumed 35-year economic life of the project to form a Benefit-Cost (B/C) ratio. Benefits are based entirely on the amount of energy supplied to the local transmission system. Project costs are comprised of the capital cost of the rehabilitation work and the present worth of operation and maintenance costs. For the City of McMinnville, the most likely developer, a discount rate of 10 percent was assumed since this is the approximate municipal bond rate.

The present worth of power benefits and operation and maintenance costs was computed for two different economic forecasts. An escalation rate of 10.5 percent was assumed for the first eleven years in the high forecast and 10.0 percent for the remainder of the economic life. In the low forecast 7.3 percent escalation was assumed for the first 11 years, 5.5 percent for the next 8 years, and 6.0 percent for the last 16 years.

The present worth of the project benefits and costs for the high forecast equals $1,448,000 and $1,231,000, respectively, resulting in a B/C ratio of 1.18. The low forecast present worth values for project benefits and costs are $858,000 and $1,096,000, respectively, which yield a B/C ratio of 0.78. Since actual values are expected to fall in between these numbers, this analysis is not sufficient to make a decision on implementation. A potential developer would need to perform a detailed financial analysis to determine if he could utilize available tax benefits from the project to produce a satisfactory return on investment.

Figure 8 shows the sensitivity of the B/C ratio to varying discount and escalation rates assuming a 35-year economic life. The B/C ratio can be significantly affected by a different prediction of the future state of the economy, a different applicable discount rate, and reduction in the total project cost.



LEGEND:
A-High escalation rate for benefits and O&M costs
B-Low escalation rate for benefits and O&M costs

Figure 8. Discount Rate vs Benefit-Cost Ratio

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X. ENVIRONMENTAL ASSESSMENT

The environmental effects of hydro projects, which have relatively small existing dams and operate as run-of-river plants, are most often minimal. This concept is consistent with independent studies made by several organizations. One such study was done by a consultant for assisting the Federal Energy Regulatory Commission (FERC) in proposing regulations to exempt certain projects from licensing as provided in Part I of the Federal Power Act. To qualify for such exemption, a candidate must be an existing dam, have a total installed capacity of less than 5 MW, and meet the following conditions:

1. Repair or reconstruction of the dam must not raise the normal maximum surface elevation of the impoundment.
2. There must not be significant existing upstream or downstream passage of fish.
3. Operation of the dam for hydropower purposes must not change the normal storage and release pattern of the impoundment.
4. The discharge from the powerhouse must be located no more than 300 feet from the toe of the dam.
5. The project must not involve construction at or alteration of a historic site.
6. If the project requires a new transmission line, it must be 69 kV or less, and the line must be shorter than one mile if located on a new right-of-way.
7. The project must not adversely affect a Federally-designated critical habitat or a Federally-designated threatened or endangered species.

8. The project must not cause violations of applicable State or Federal water quality standards.

The possible redevelopment of the McMinnville Dam project meets all of the above conditions. Therefore, it is anticipated that long term environmental effects would not be a significant deterrent to the rehabilitation. Short term environmental effects caused by the construction, such as an increase in the turbidity of the water and construction noise, would be minimized by proper construction techniques and would be only temporary.

It should be noted that in relation to item (5), McMinnville Dam is currently being considered for inclusion on the list of sites eligible for inclusion in the National Register of Historic Places.

XI. DAM SAFETY ASSESSMENT

The existing dam, as described earlier, consists of two sections. The left is a timber crib structure overlain with concrete and the right is a concrete gravity structure. The right section was reconstructed in 1929 and presents no known safety problems. However, at almost 80 years old, the integrity of the left section is particularly suspect. It is similar in construction to the portion which washed away in 1929, and it is reasonable to assume that in its present condition the left section could also be destroyed by flooding. The damage incurred by such failure would be minimal since there is no significant development downstream and since there is little difference between headwater and tailwater elevations during heavy flooding. However, the lower headwater elevation resulting from the

failure could adversely affect the submergence of the McMinnville water supply intake and would also render a renovated hydroplant useless.

Strengthening the existing dam would be a prohibitively expensive item and is not included in the cost estimate. Rehabilitation would entail construction of cofferdams upstream and downstream, and replacing the old dam section with a new concrete gravity structure.

XII. CONCLUSIONS AND RECOMMENDATIONS

Based on the analysis made in this study, the feasibility of restoring the power facilities at McMinnville Dam would be marginal. Depending upon the economic forecast assumed, the Benefit-Cost ratio ranges between 0.78 and 1.18 at a 10 percent discount rate.

Favorable economics would depend on the developer's ability to reduce costs, his ability to secure low interest financing, and his financial situation being such that he could take advantage of tax benefits available to small hydro investors.

There are also some disadvantages to be considered. The developer should be aware that there could be negative cash flows for the first several years of operation until escalating benefits reach and surpass costs. Another important consideration is the suspect integrity of the existing structure. Dam failure would terminate operation of a rehabilitated hydroplant and cause a substantial loss of capital since the cost of rebuilding the dam would be prohibitive.

If the developer can meet the above conditions and is willing to take the associated risks, it is recommended that a detailed financial analysis be performed. A decision on whether or not to proceed with redevelopment can then be made.

View of dam and powerhouse

APPENDIX

F

OLD Columbia DAM

APPENDIX F

FEASIBILITY REPORT - OLD COLUMBIA DAM

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SUMMARY OF PRINCIPAL FEATURES

Old Columbia Dam

Location
On the Duck River at Mile 133.53, in Columbia, Tennessee

Owner
City of Columbia

Streamflow	
Drainage area	1206 sq. miles
Average discharge	2000 cfs
Tailwater	
Normal operating	El. 542.0
Minimum	El. 541.4
Operating Heads (net)	
Maximum	14.0 ft
Minimum	4.8 ft
Rated	12.8 ft
Dam	
Type	concrete gravity
Length	572 ft
Height	22 ft
Top of spillway	El. 555.5
Possible Power Facilities	
Existing powerhouse	46 ft x 31 ft reinforced concrete and masonry
Hydraulic turbines	
Number	two
Type	Francis, vertical shaft, open flume
Rated output	515 hp each, 1030 hp total
Runner diameter	45 in
Generator	
Type	induction, horizontal shaft
Rating	365 kW each, 730 kW total
Plant Output:	
Average annual energy	3,200,000 kWh
Cost	
Total project cost	$2,220,000
Cost per kW	$3,030

SUMMARY

This report presents the results of a study to determine the feasibility of restoring the hydroelectric generating facilities at Old Columbia Dam. The costs used for this report reflect construction costs experienced by TVA including overheads normally used in TVA accounting procedures and may or may not apply to a developer.

The evaluation of several alternative plans using TVA costs and benefits and an assumed discount rate indicates that the redevelopment of Old Columbia Dam could be economically feasible to a developer whose financial situation is suitable. A detailed financial analysis would be required by a developer to assist in reaching a final decision on project implementation.

I. INTRODUCTION

The purpose of this report is to investigate the possibility of restoring hydroelectric power generation facilities at the Old Columbia Dam on the Duck River in Columbia, Tennessee.

This report is part of the second phase of TVA's Small Hydro Program which was begun in 1979 to investigate the potential for small scale hydroelectric power production in the Tennessee Valley Region. The first phase, which was completed in June 1980, consists of an inventory and screening of existing non-Federal dams in the Tennessee Valley and the TVA power service area. The second phase consists of more detailed feasibility studies on ten of the most promising sites based on the results of the reconnaissance phase.

Included in the feasibility analysis for Old Columbia Dam is a detailed cost estimate, evaluation of project benefits, and computation of a Benefit-Cost ratio. A potential developer can use these to help make a decision regarding whether or not to proceed with rehabilitation of the facility.

II. SITE HISTORY

Old Columbia Dam and Powerhouse was built by the Southern Cities Power Company of Chattanooga in 1925. Unit one was placed in service in 1925 and the second unit was online in 1926. Southern Cities operated the plant until 1929 when it was acquired by the Tennessee Electric Power Company. The powerhouse contained two 570 horsepower vertical Francis-type turbines manufactured by Leffel. The turbines were

controlled by Woodward oil pressure governors and were connected directly to vertical 400 kW Westinghouse synchronous generators. By 1931 the operation of the plant was classified as semi-automatic. The Tennessee Valley Authority acquired the project in 1939 and operated it until its retirement in 1961. On retirement, the generating equipment was sold for scrap and the dam was sold to the city of Columbia.

III. SITE DESCRIPTION

A. General

Old Columbia Dam is located on the Duck River (Mile 133.53) within the corporate limits of the city of Columbia, Tennessee (see Figures 1 and 2). Riverside Drive passes the right abutment of the dam and provides easy access to the project. The major features of the project consist of a dam and a powerhouse located near the center of the dam (see Figure 3). The powerhouse is accessible by a bridge from the right abutment.

Currently the major purpose of the reservoir is water supply for Columbia. The water treatment plant intake is located approximately one-half mile upstream from the dam on the right bank of the reservoir. Columbia's average daily consumption is 6.2 million gallons per day (9.6 cfs) with a treatment plant capacity of 9.2 million gallons per day (14.2 cfs).

B. Dam

The dam is a concrete gravity structure approximately 22 feet high and 572 feet long. It is composed of a nonoverflow section, four spillway sections and powerhouse.

Figure I. Location Map

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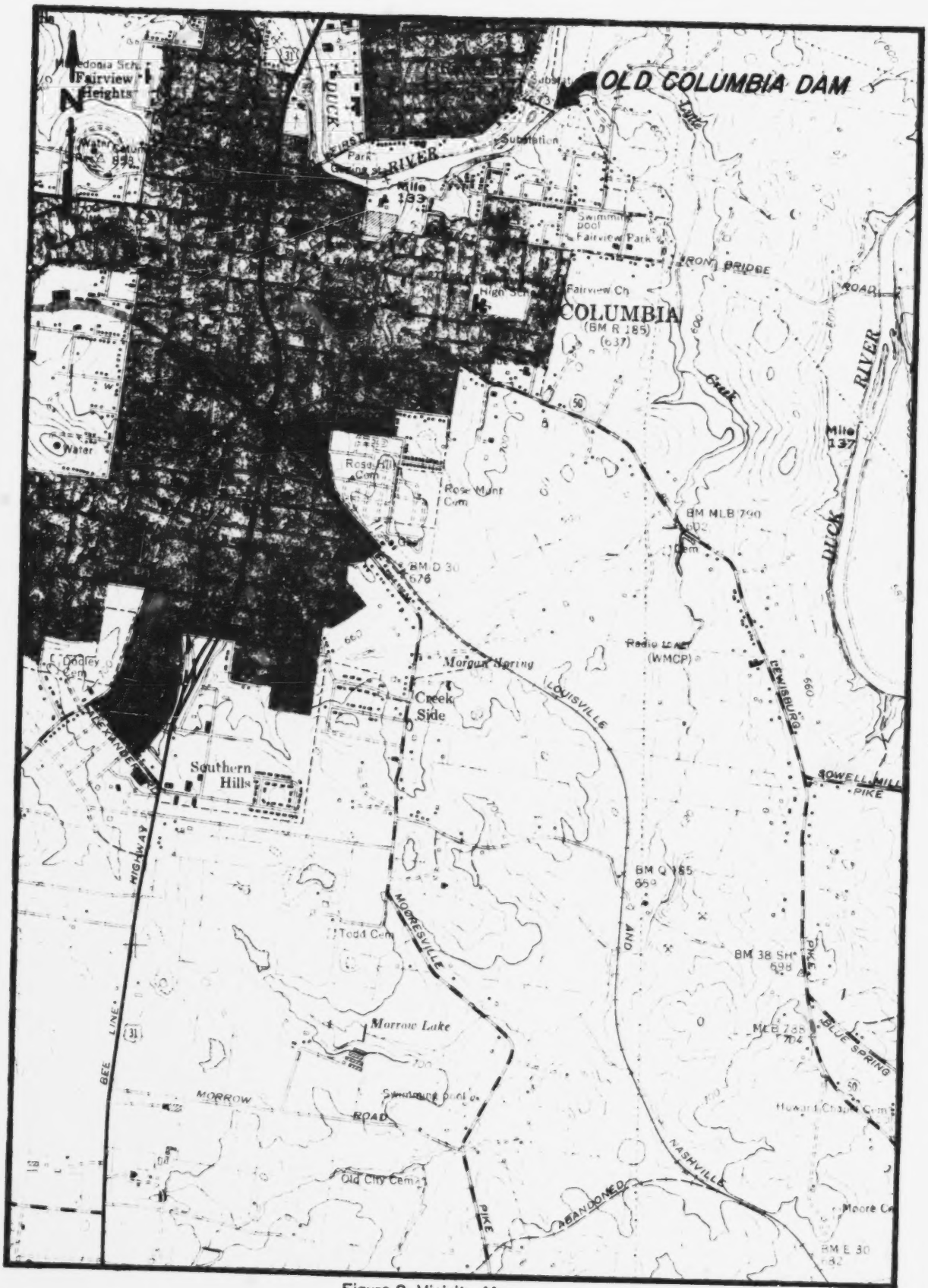

Figure 2. Vicinity Map

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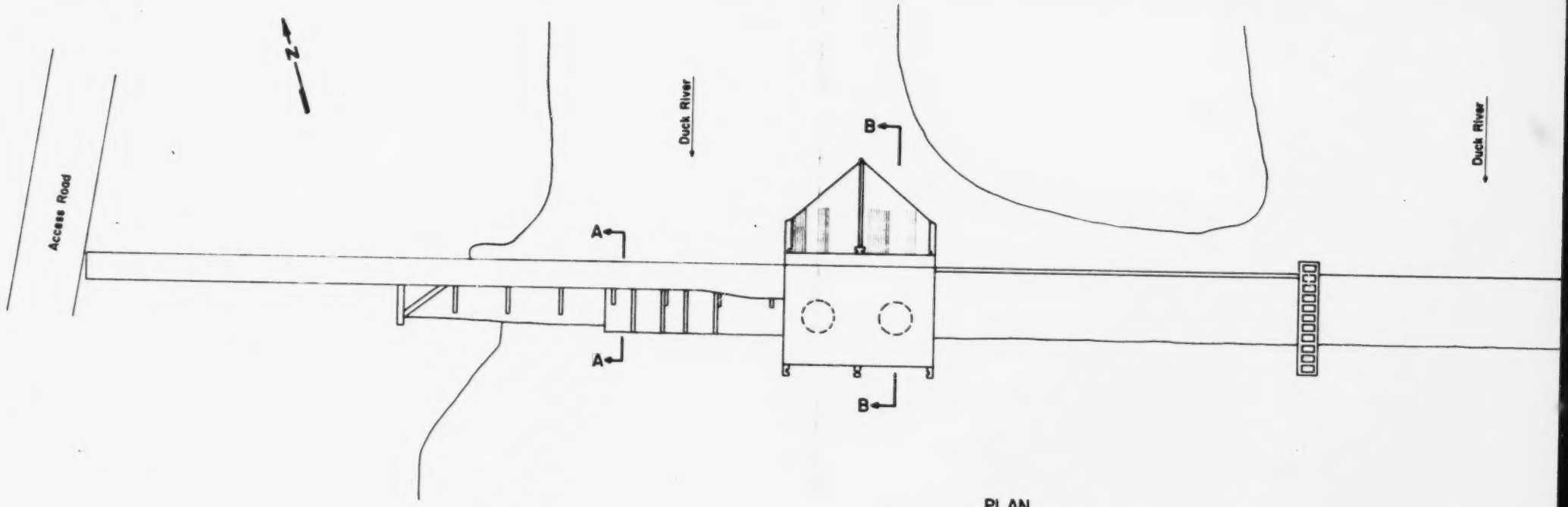

PLAN

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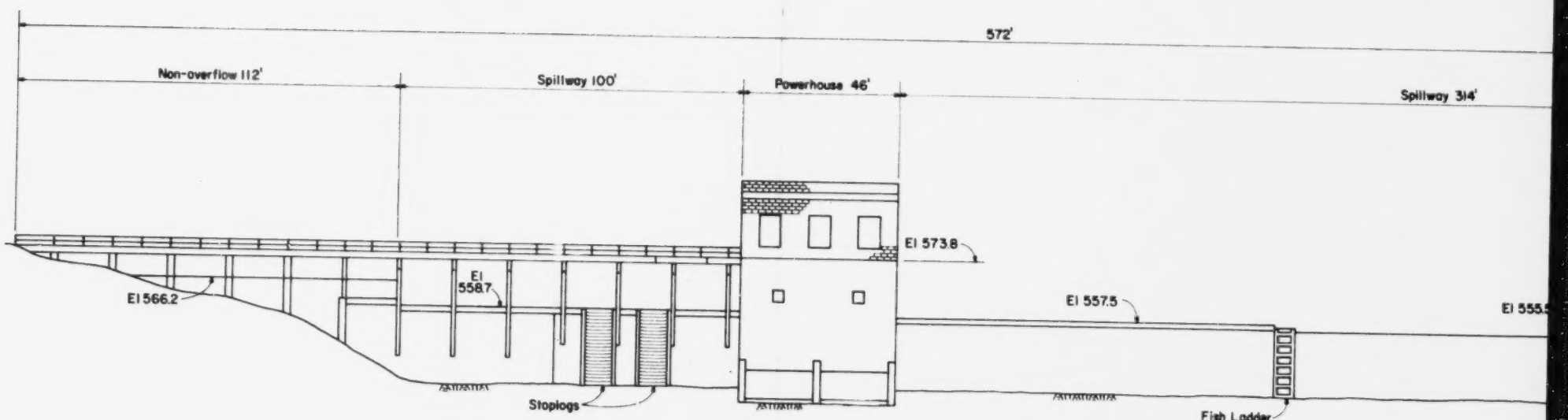

DOWNSTREAM ELEVATION

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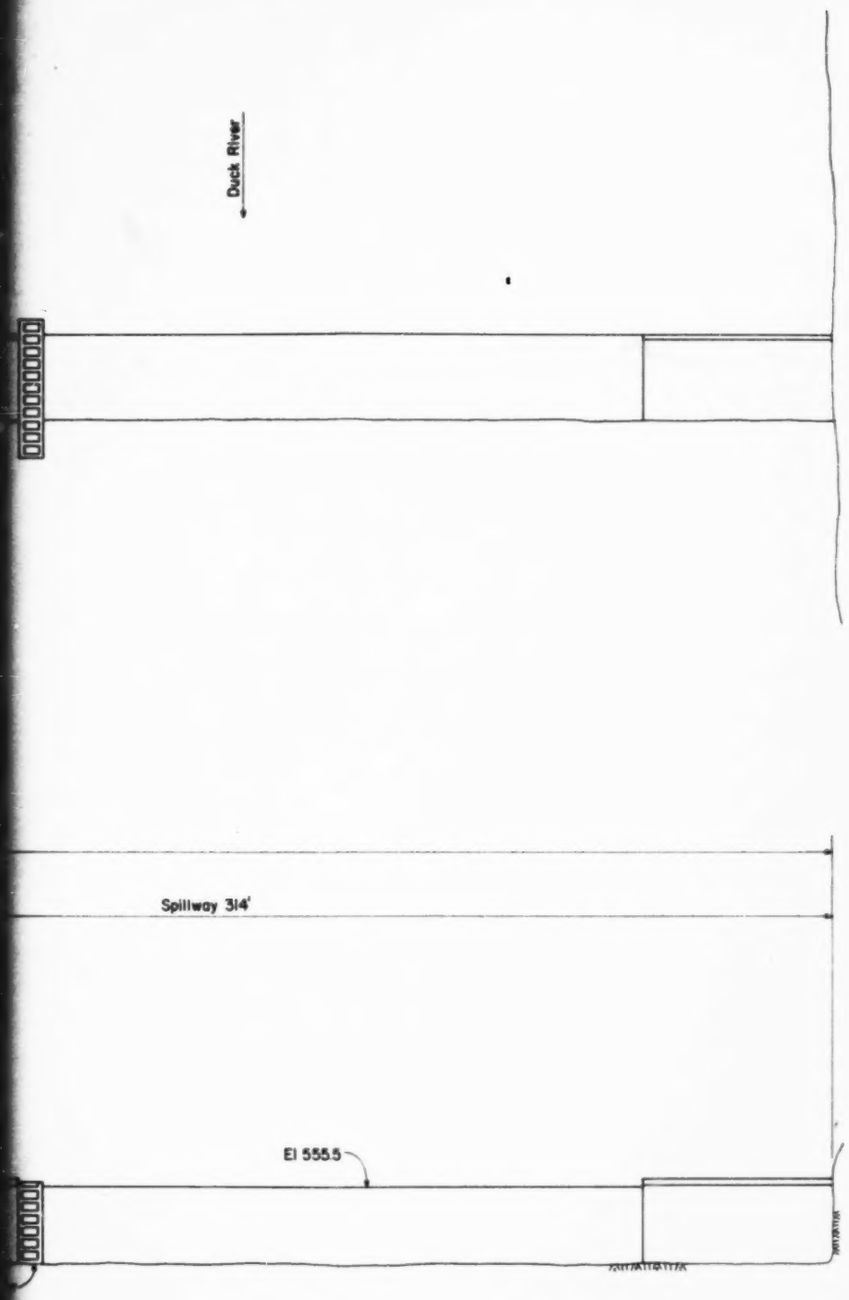

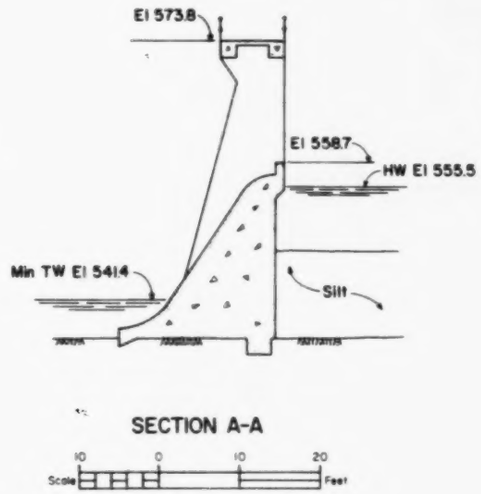

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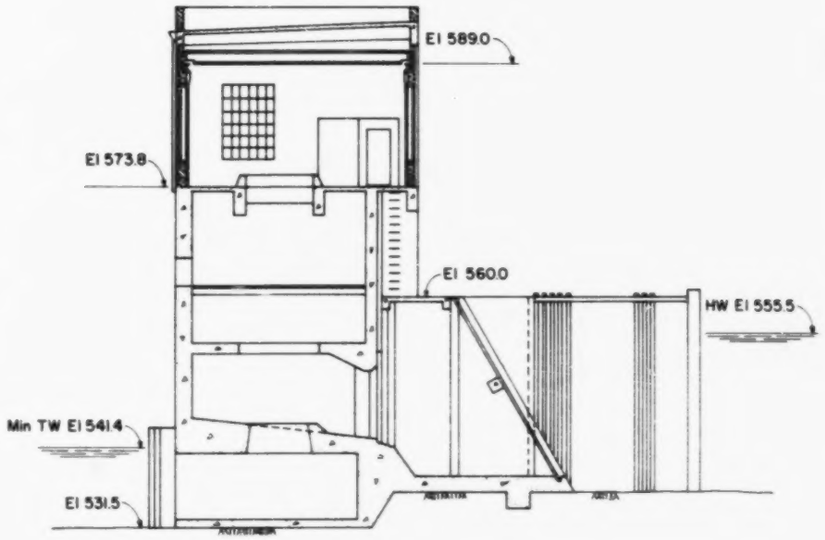

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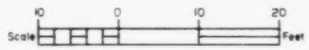

Figure 3. Existing Facilities - Old Columbia Dam

The nonoverflow section forms the right abutment of the dam. It is 112 feet long and has a crest elevation of 566.2 feet. An ogee spillway section is located between the nonoverflow section and powerhouse. This uncontrolled section has two sets of 8-foot by 22-foot stoplogs and is 100 feet long, with a crest elevation of 558.7 feet. Both the nonoverflow and spillway sections support the piers of the powerhouse access bridge. To the left of the powerhouse is a 111-foot uncontrolled ogee spillway with a crest elevation of 557.5. Adjoining this, with a 6-foot wide fish ladder and a crest elevation of 555.5, is a third ogee section 156 feet in length. Finally, another ogee section with a crest elevation of 557.5 extends 47 feet to the river bank. There is minor concrete spalling visible and minor seepage from the limestone bed below the right abutment and some of the stoplogs need replacing. The dam, in the past, has been overtopped numerous times without any major structural failure or evidence of slippage. Preliminary stability analysis of the dam indicates that it is safe from failure by overturning and sliding.

C. Powerhouse

The powerhouse is a reinforced concrete and masonry structure located approximately 210 feet from the right bank. Access to the powerhouse is via an 8-ft wide reinforced concrete bridge. The powerhouse is 46 feet long, 31 feet wide, and 65 feet high. It will accommodate two vertical turbines in an open flume configuration. The only remaining equipment in the powerhouse is a 10-ton overhead crane and six intake gates which are blocked by an accumulation of silt. The interior of the powerhouse needs cleaning and window replacement, and the parapet above the roof is in poor shape. The handrails on the access bridge are bent by past flooding and need replacing.

D. Switchyard

Old Columbia's switchyard is located just upstream of the dam on Riverside Drive. All that remains of the switchyard equipment are metal transformer frames and a metal building. There is a 46 kV transmission line located 0.1 mile from the dam.

IV. HYDROLOGY AND HYDRAULICS

The Duck River originates just north of Manchester, Tennessee, and flows approximately 280 miles through Middle Tennessee before emptying into Kentucky Lake at Tennessee River Mile 110.7. The Old Columbia Dam at Duck River Mile 133.53 impounds a small reservoir with no appreciable storage and provides water supply for the City of Columbia. Withdrawal for this purpose amounts to a very small portion of the average streamflow. The average annual rainfall on the watershed above Columbia is approximately 53 inches. Based on 63 years of record at a USGS gage just below the dam, average flow at the dam is 2,000 cfs and the minimum flow of record is 0 cfs, occurring in 1922. The maximum flood of record at Old Columbia Dam occurred on March 16, 1973, and had a peak flow of 61,500 cfs. This flood crested at approximately 33 feet above the dam's spillway.

TVA is presently constructing Columbia Dam on the Duck River at Mile 136.9. This dam will reduce the magnitude of flooding at the city of Columbia and at Old Columbia Dam and will provide a minimum regulated flow of 215 cfs at Old Columbia Dam. The regulated 100-year flood discharge at Old Columbia Dam has been computed to be 30,000 cfs and would result in the water surface elevation rising to just below the generator floor (El. 573.0).

A flow duration curve was generated utilizing simulated flow from TVA's Duck River operation study (see Figure 4). These flows were computed assuming completion of TVA's Columbia Dam. They were composed of theoretical discharge from TVA's Columbia Dam and uncontrolled flow between the Old Columbia Dam and the Columbia Dam based on the USGS gage immediately downstream from Old Columbia Dam. The drainage area at this gage is 1208 square miles.

V. PROJECT DEVELOPMENT

In selecting the best redevelopment plan for the project, several alternatives were considered. Emphasis was placed on minimizing civil works, selecting a standardized turbine, choosing an installation similar in size to the original units, and ensuring that any adverse impacts on the environment be minimized.

To comply with these conditions, all alternatives would provide run-of-river operation of the hydroplant and would utilize the existing powerhouse. It was determined that the following two types of units would show the most promise of rendering a viable project:

1. Vertical Francis Type S turbine manufactured by The James Leffel and Company
2. Standard low head Mini TUBE turbine manufactured by Allis Chalmers.

The units selected as the best alternative for utilization at Old Columbia Dam are two 48-inch type S turbines. These units have Francis runners and are primarily controlled by wicket gates located at the turbine

inlet (Figure 5). The units are designed to operate in the present configuration of the powerhouse. Placement would require minor modification to the generator floor.

The horizontal shaft generators rated at 365 kW each, for a total of 730 kW, would connect to the turbines through speed increasers which would be mounted on steel plates covering the existing generator floor openings. Power produced would be fed to nearby transmission lines.

Other major construction items include:

1. Dredge silt upstream from powerhouse
2. Repair windows and intake gates
3. Clean out powerhouse
4. Install necessary mechanical and electrical equipment.

Sufficient cover on the existing water supply intake would be assured by installing automatic headwater level control equipment which would limit reservoir fluctuation to less than one foot below top of dam.

VI. POWER PRODUCTION

Operation of the proposed hydroplant would be run-of-river. The potential power was determined utilizing the duration of flow curve shown in Figure 4. Usable flow under the curve was divided into several increments and average annual generation was computed by summing the potential energy from each increment under the curve. For this computation, a specific efficiency value was assigned to each increment of flow based on manufacturer's unit performance curves and net heads were computed using a tailwater curve and accounting for losses in the system.

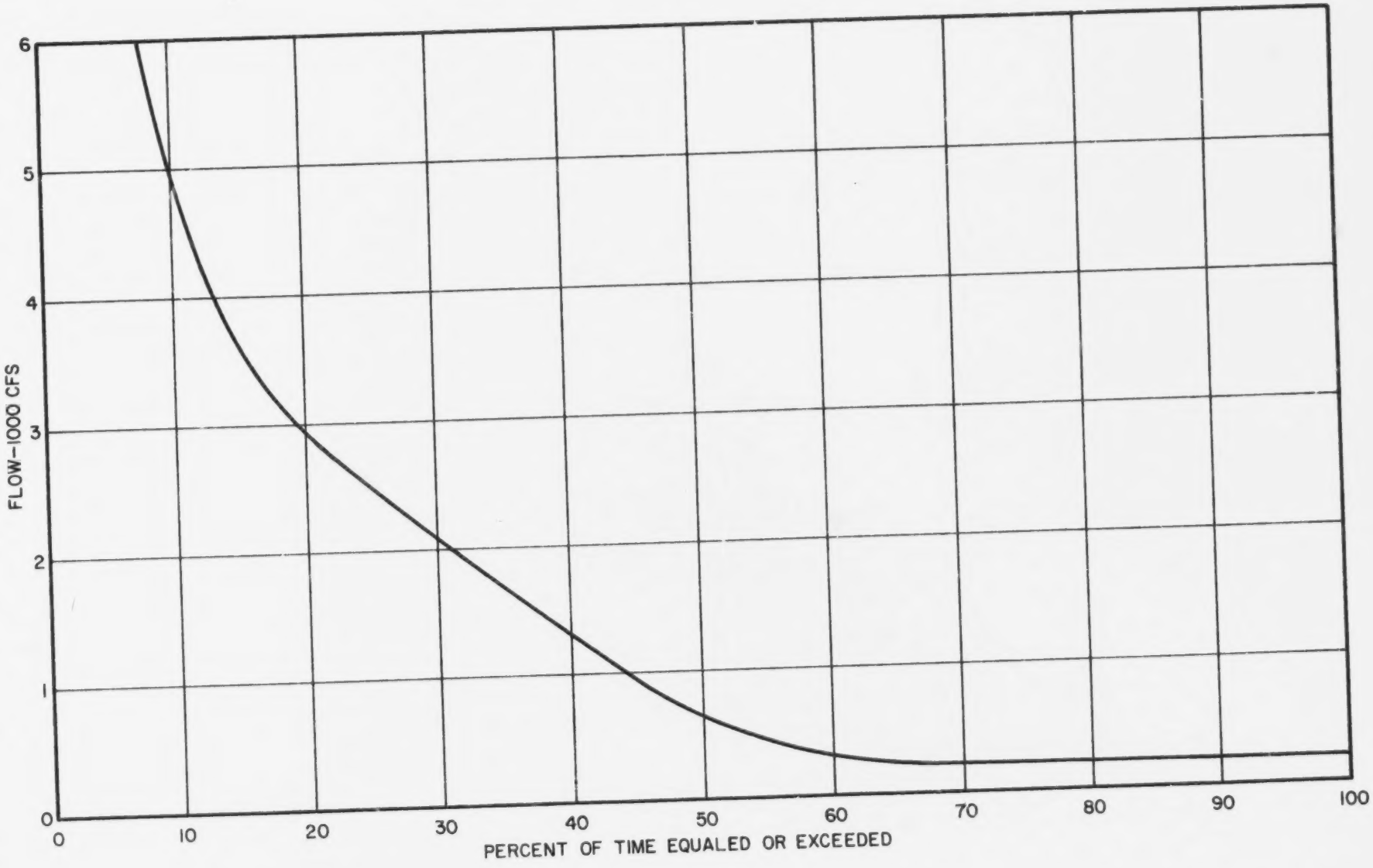

Figure 4. Duration of Flow

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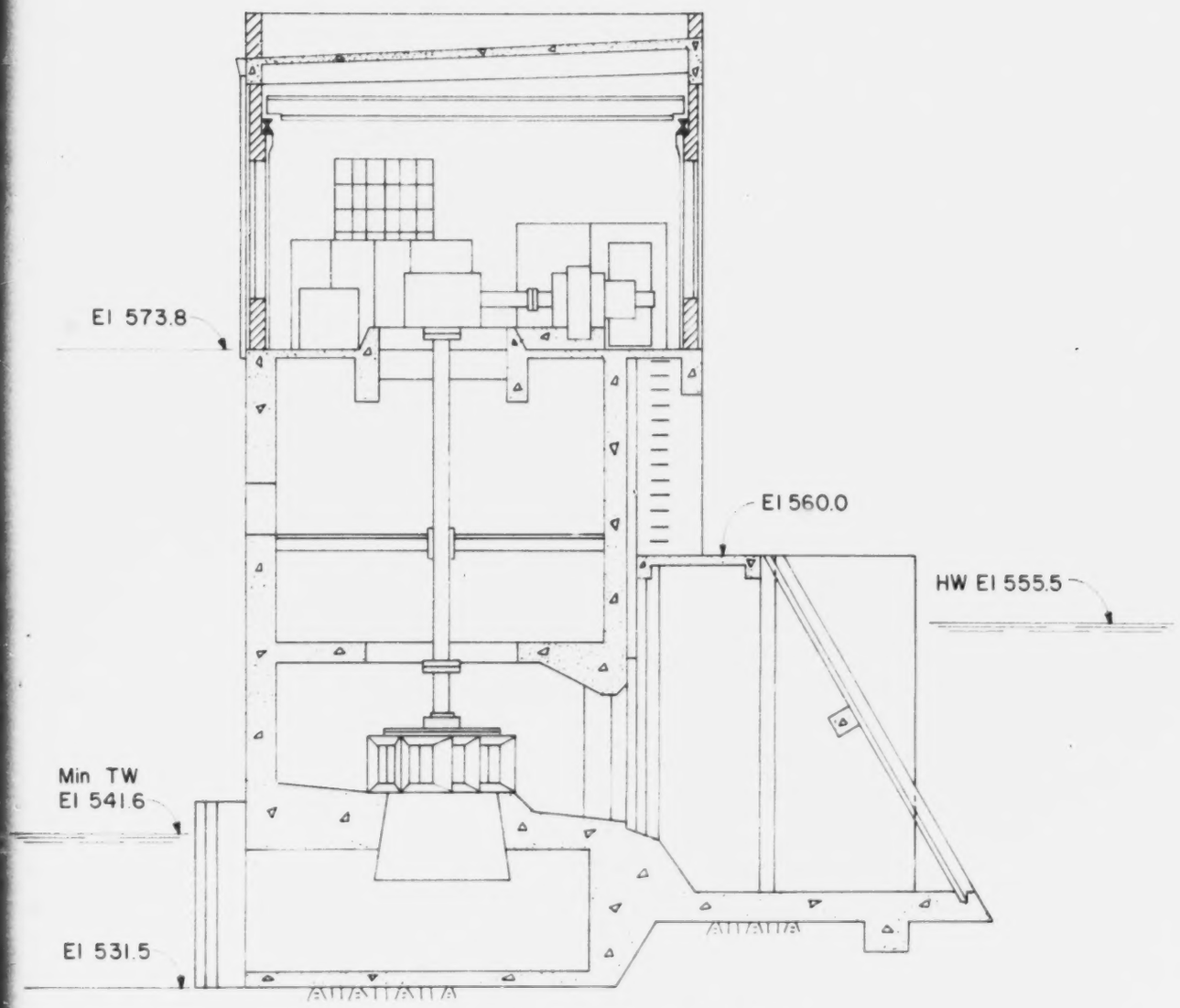
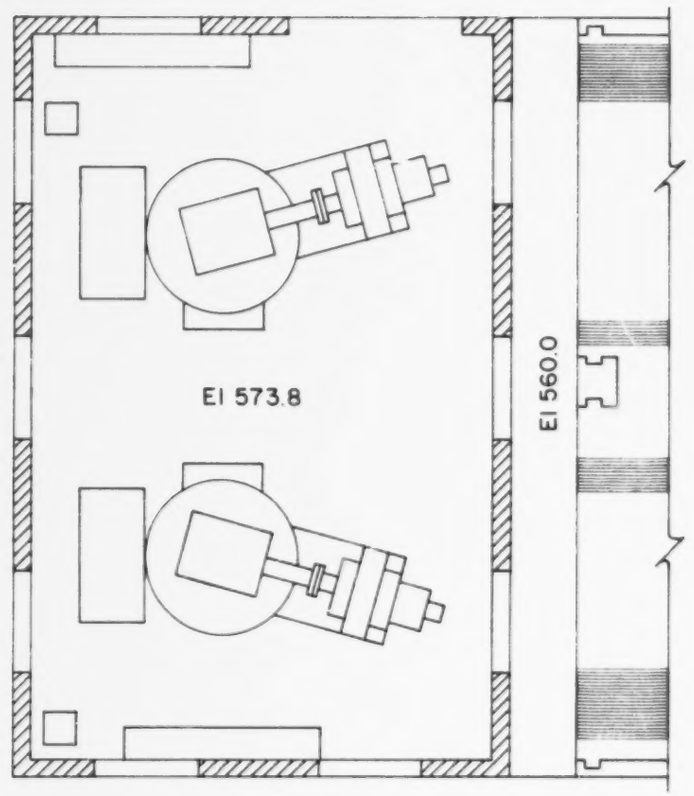


SECTION THRU POWERHOUSE



PLAN-GENERATOR FLOOR

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Figure 5. Possible Redevelopment Plan-Old Columbia Dam

Average annual energy which could be produced by two 48-inch S turbine units was estimated to be 3,200,000 kWh. At full gate (432 cfs), each unit would be rated at 365 kW with an overall efficiency of 78 percent at 12.8 ft net head.

VII. PROJECT COSTS

The project cost in 1981 dollars of the most feasible redevelopment plan is $2,220,000, and is comprised of estimates of equipment and structural costs, interest during construction, contingencies, and overheads. The major items in the estimate are electrical and mechanical equipment, repair and alteration of the existing facilities, and site preparation. A summary of these costs is shown in Figure 6. Electrical items, contingencies, overheads, and unit costs are based on TVA costs, and the generating equipment costs were obtained from the manufacturer. Operation and maintenance costs are assumed to be $20,000 per year in 1981 dollars.

It should be pointed out that the costs presented in this estimate are conservatively high and are not necessarily applicable to all potential developers. There could be some cost savings if suitable used equipment could be acquired or if the developer could provide labor and materials at a lower cost.

VIII. PROJECT BENEFITS

Benefits from the possible hydro facility are based on the amount of energy made available to the local transmission system. The Public

Utility Regulatory Policies Act of 1978 (PURPA) requires a utility to purchase any energy offered for sale by a qualifying facility. The value of this energy is determined using the rates adopted by TVA under its Dispersed Power Production Policy. The energy price as of October 1981 is 4.489 cents/kWh during peak periods, and 2.826 cents/kWh during off-peak periods, for plants having 100 kW or greater capacity. Since plant operation at Old Columbia Dam would use the available inflow without regard to the time of day, the weighted average of these two rates, 3.407 cents/kWh, has been used to evaluate the energy production. Using this value, the potential average annual generation of 3,200,000 kWh at Old Columbia Dam is worth approximately $109,000. The energy value is subject to change in accordance with the adjustment provisions of TVA's wholesale power contracts.

IX. ECONOMIC ANALYSIS

The feasibility of restoring the hydro facilities at Old Columbia Dam was evaluated by comparing the present worth of the project's benefits and costs over an assumed 35-year economic life of the project to form a Benefit-Cost (B/C) ratio. Benefits are based entirely on the amount of energy supplied to the local transmission system. Project costs are comprised of the capital cost of the rehabilitation work and the present worth of operation and maintenance costs. For the city of Columbia, the most likely developer, a discount rate of 10 percent was assumed since this is the approximate municipal bond rate.

The present worth of power benefits and operation and maintenance costs was computed for two different economic forecasts. An escala-

OLD COLUMBIA DAM

HYDROELECTRIC PLANT REHABILITATION

Estimate of Cost[1]

General Yard Improvements	$ 5,000
Powerhouse	47,000
Reservoir	25,000
Intake	14,000
Turbine and Generator Equipment	1,155,000
Electrical Equipment	81,000
Construction Facilities	166,000
Total Direct Construction	$1,493,000
Field General Expense	105,000
Contingency	188,000
Total Field Construction	1,786,000
Interest During Construction	125,000
Total Construction	1,911,000
Engineering Design	224,000
Administration	85,000
Total Project	$2,220,000

[1]Total project cost is based on 1981 dollars. This estimate does not include the primary reclosure or the 132 kV to 480 volt transformer.

Figure 6: Cost Estimate

tion rate of 10.5 percent was assumed for the first eleven years in the high forecast and 10.0 percent for the remainder of the economic life. In the low forecast 7.3 percent escalation was assumed for the first 11 years, 5.5 percent for the next 8 years, and 6.0 percent for the last 16 years.

The present worth of the project benefits and costs for the high forecast equals $3,603,000 and $2,929,000, respectively, resulting in a B/C ratio of 1.23. The low forecast present worth values for project benefits and costs are $2,136,000 and $2,628,000, respectively, which yield a B/C ratio of 0.81. Since actual values are expected to fall in between these numbers, this analysis is not sufficient to make a decision on implementation. A potential developer would need to perform a detailed financial analysis to determine if he could utilize available tax benefits from the project to produce a satisfactory return on investment.

Figure 7 shows the sensitivity of the B/C ratio to varying discount and escalation rates assuming a 35-year economic life. The B/C ratio can be significantly affected by a different prediction of the future state of the economy, a different applicable discount rate, and reduction in the total project cost.

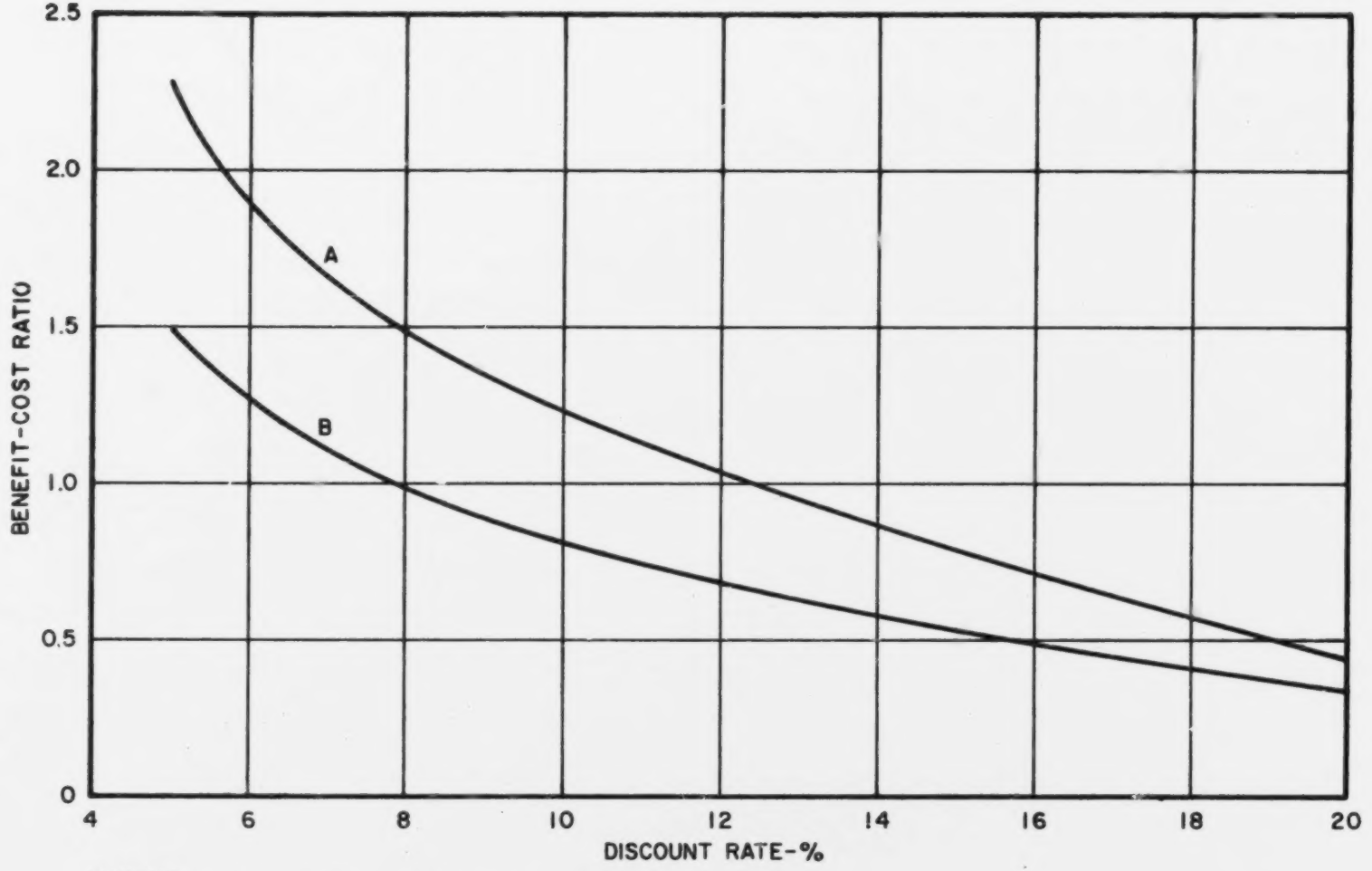
X. ENVIRONMENTAL ASSESSMENT

The environmental effects of hydro projects, which have relatively small existing dams and operate as run-of-river plants, are most often minimal. This concept is consistent with independent studies made by several organizations. One such study was done by a consultant for assisting the Federal Energy Regulatory Commission (FERC) in proposing regulations to exempt certain projects from licensing as provided in Part I

of the Federal Power Act. To qualify for such exemption, a candidate must be an existing dam, have a total installed capacity of less than 5 MW, and meet the following conditions:

1. Repair or reconstruction of the dam must not raise the normal maximum surface elevation of the impoundment.
2. There must not be significant existing upstream or downstream passage of fish.
3. Operation of the dam for hydropower purposes must not change the normal storage and release pattern of the impoundment.
4. The discharge from the powerhouse must be located no more than 300 feet from the toe of the dam.
5. The project must not involve construction at or alteration of a historic site.
6. If the project requires a new transmission line, it must be 69 kV or less, and the line must be shorter than one mile if located on a new right-of-way.
7. The project must not adversely affect a Federally-designated critical habitat or a Federally-designated threatened or endangered species.
8. The project must not cause violations of applicable State or Federal water quality standards.

The possible redevelopment of the Old Columbia Dam meets all of the above conditions. Therefore, it is anticipated that long term environmental effects would not be a significant deterrent to the rehabilitation. Short term environmental effects caused by the construction, such as an increase in the turbidity of the water and construction noise, would be minimized by proper construction techniques and would be only temporary.



LEGEND:
A-High escalation rate for benefits and O&M costs
B-Low escalation rate for benefits and O&M costs

Figure 7. Discount Rate vs Benefit-Cost Ratio

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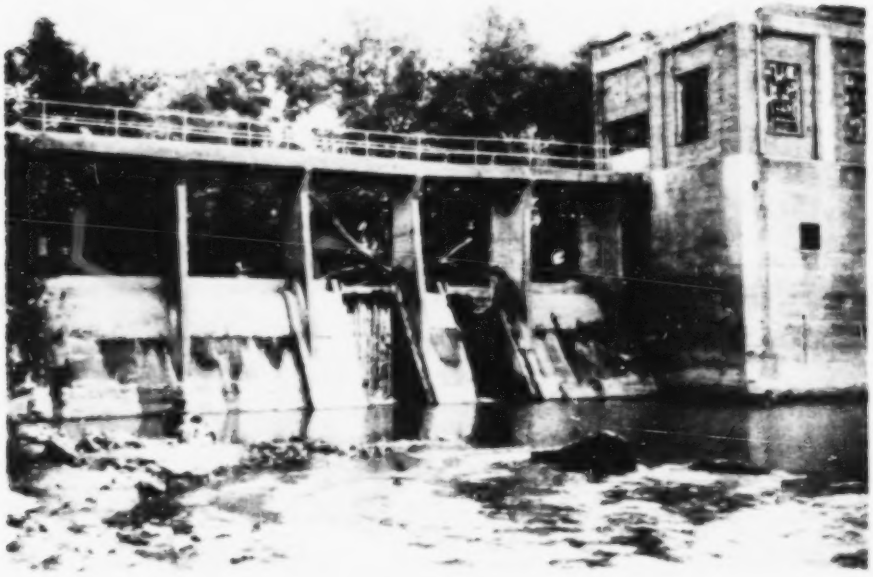
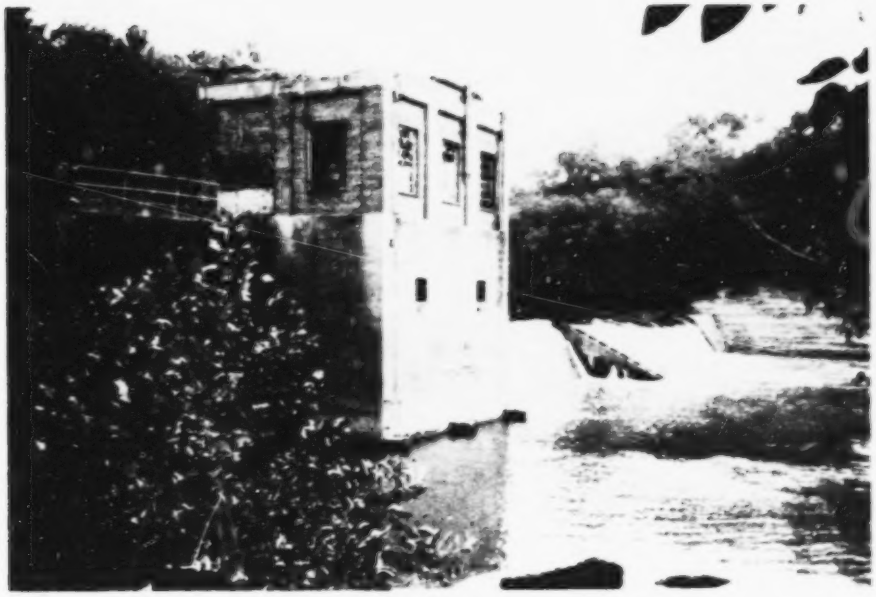
XI. CONCLUSIONS AND RECOMMENDATIONS

Based on the analysis made in this study, the feasibility of restoring the power facilities at Old Columbia Dam would be marginal. Depending upon the economic forecast assumed, the Benefit-Cost ratio ranges between 0.81 and 1.23 at a 10 percent discount rate. The developer should be aware that there could be negative cash flows for the first several years of operation until escalating benefits reach and surpass costs.

Favorable economics would depend on the developer's ability to reduce costs, his ability to secure low interest financing, and his financial situation being such that he could take advantage of tax benefits available to small hydro investors. It is recommended that a detailed financial analysis be performed to help determine whether or not to proceed with redevelopment.



Downstream view of dam and powerhouse



Oblique view of powerhouse and dam

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APPENDIX G

Shelbyville DAM

APPENDIX G

FEASIBILITY REPORT - SHELBYVILLE DAM

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SUMMARY OF PRINCIPAL FEATURES

Shelbyville Dam

Location
On the Duck River at Mile 221.4, in Bedford County, Tennessee

Owner
City of Shelbyville

Streamflow	
Drainage area	425 sq. miles
Average discharge	730 cfs
Tailwater	
Normal operating	El. 701.5
Minimum	El. 700.0
Operating Heads (net)	
Maximum	11.8 ft
Minimum	3.5 ft
Rated	10.5 ft
Dam	
Type	concrete gravity
Length	430 ft
Height	18 ft
Spillway length	185 ft
Top of spillway	El. 713
Possible Power Facilities	
Existing powerhouse	30 ft x 45 ft reinforced concrete and brick
Hydraulic turbines	
Number	one
Type	Francis, vertical shaft, open flume
Runner diameter	48 in
Generator	
Type	induction, horizontal shaft
Rating	230 kW
Plant output:	
Average annual energy	1,300,000 kWh
Cost	
Total project cost	$890,000
Cost per kW	$3,900

SUMMARY

This report presents the results of a study to determine the feasibility of restoring the hydroelectric generating facilities at Shelbyville Dam. The costs used for this report reflect construction costs experienced by TVA including overheads normally used in TVA accounting procedures and may or may not apply to a developer.

The evaluation of several alternative plans using TVA costs and benefits and an assumed discount rate indicates that the redevelopment of Shelbyville Dam could be economically feasible to a developer whose financial situation is suitable. A detailed financial analysis would be required by a developer for him to reach a final decision on project implementation.

I. INTRODUCTION

The purpose of this report is to investigate the possibility of restoring hydroelectric generation facilities at the Shelbyville Dam on the Duck River in Bedford County, Tennessee.

This report is part of the second phase of TVA's Small Hydro Program which was begun in 1979 to investigate the potential for small scale hydroelectric production in the Tennessee Valley Region. The first phase, which was completed in June 1980, consists of an inventory and screening of existing non-Federal dams in the Tennessee Valley and the TVA power service area. The second phase consists of more detailed feasibility studies on ten of the most promising sites based on the reconnaissance phase.

Included in the feasibility analysis for Shelbyville Dam is a detailed cost estimate, evaluation of project benefits, and computation of a Benefit-Cost ratio. A potential developer can use these to help make a decision regarding whether or not to proceed with rehabilitation of the facility.

II. SITE HISTORY

The history of hydroelectric production at the present location of Shelbyville Dam dates back to the year 1915. A modern brick powerhouse was built at the end of the old dam in which was installed a 250 kilowatt generator, driven by two vertical turbines.

In 1924 the old Shelbyville plant was replaced by a new concrete dam and powerhouse. Only one unit with an installed capacity of 216 kW

was installed at that time. In 1927 another unit with an installed capacity of 216 kW was added.

The Tennessee Electric Power Company (TEPCO) acquired the property in 1929. In 1931 the electrical equipment which was damaged during the flood of 1929 was rebuilt and equipment was installed to give semi-automatic operation. The plant was operated by TEPCO mainly for voltage regulation purposes in its combined system until August 15, 1939, when the plant was acquired by TVA. The plant was operated by TVA until February 12, 1948, when it was withdrawn from service availability. The project was officially retired on July 26, 1949, and was subsequently sold to the city of Shelbyville for $3,700 on November 14, 1950.

III. SITE DESCRIPTION

A. General

Shelbyville Dam is located in Shelbyville, Tennessee, on the Duck River at Mile 221.4 in Bedford County (see Figures 1 and 2). The major features of the project consist of a dam, composed of three distinct sections, and two powerhouses (see Figure 3). Access to the west section of the dam is via U.S. Highway 231 and is very good. Access to the east section of the dam and powerhouse is via city street and is difficult. A masonry wall and steep bank approximately 30 feet high hampers access down to this area.

Currently the major purpose of the reservoir is water supply for Shelbyville. Intakes are located on the right bank approximately 0.5 miles upstream of the dam. The average daily production of the water plant is 3.25 million gallons. The reservoir and tailwater are utilized by fishermen

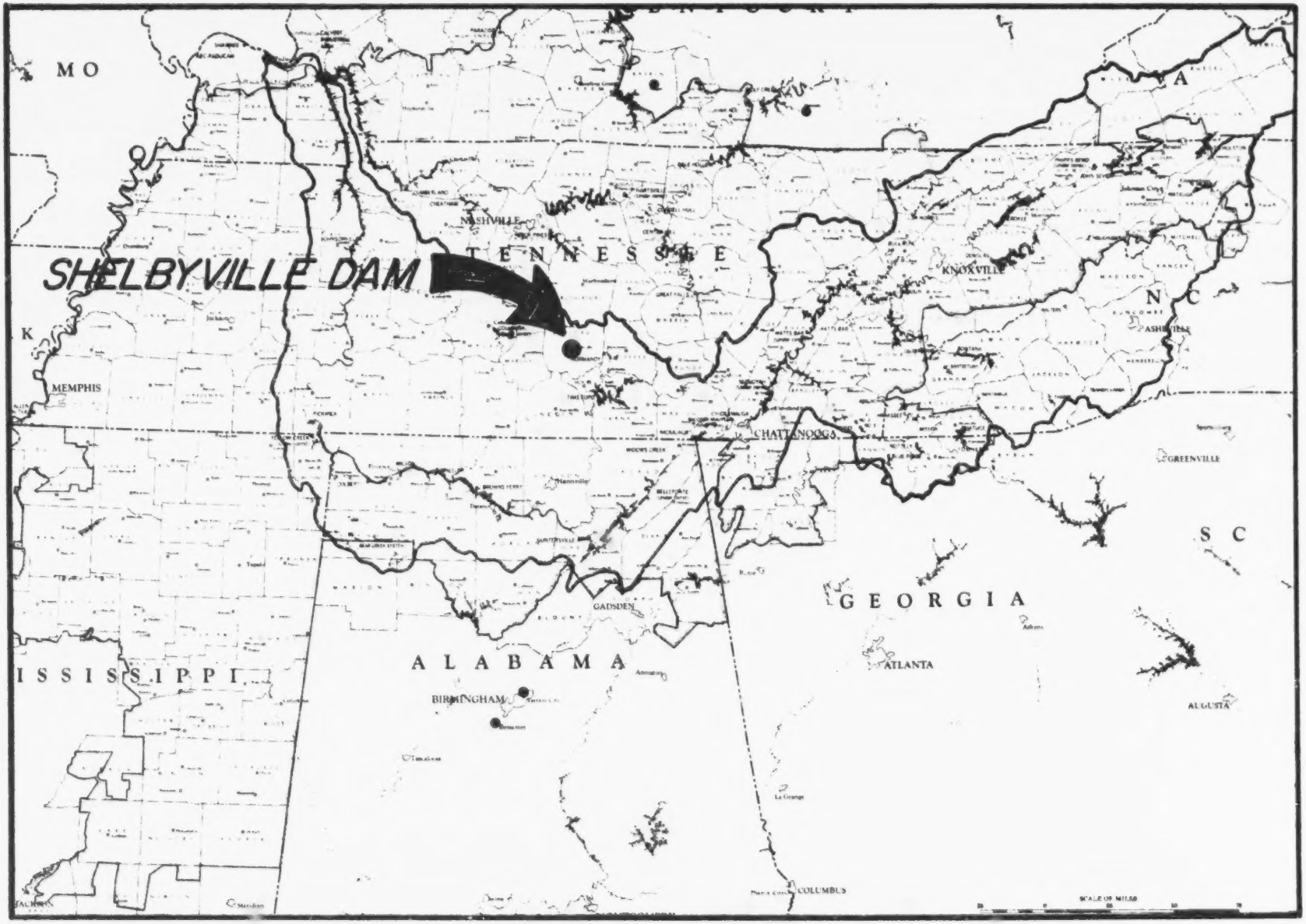

Figure I. Location Map

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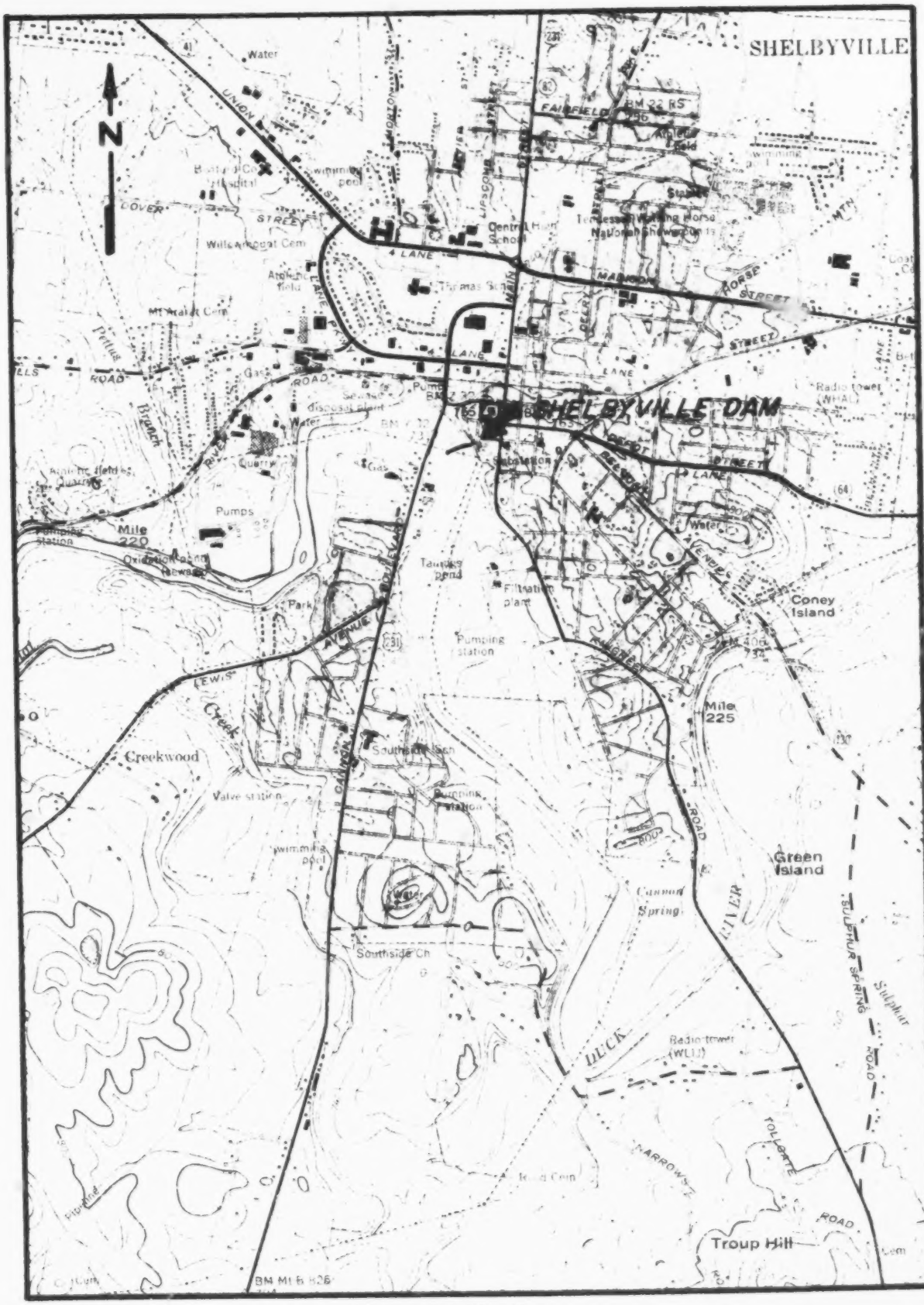

Figure 2. Vicinity Map

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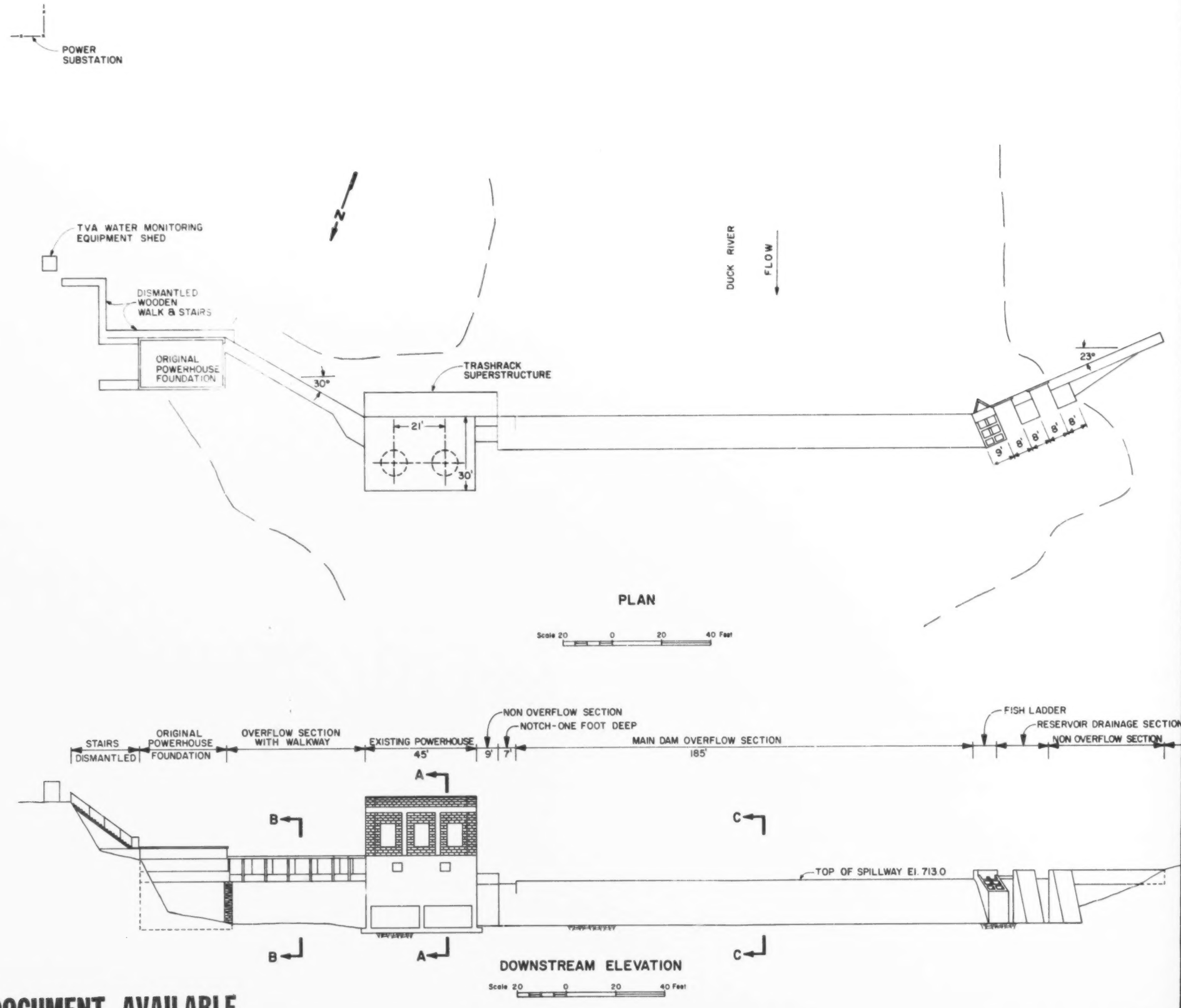

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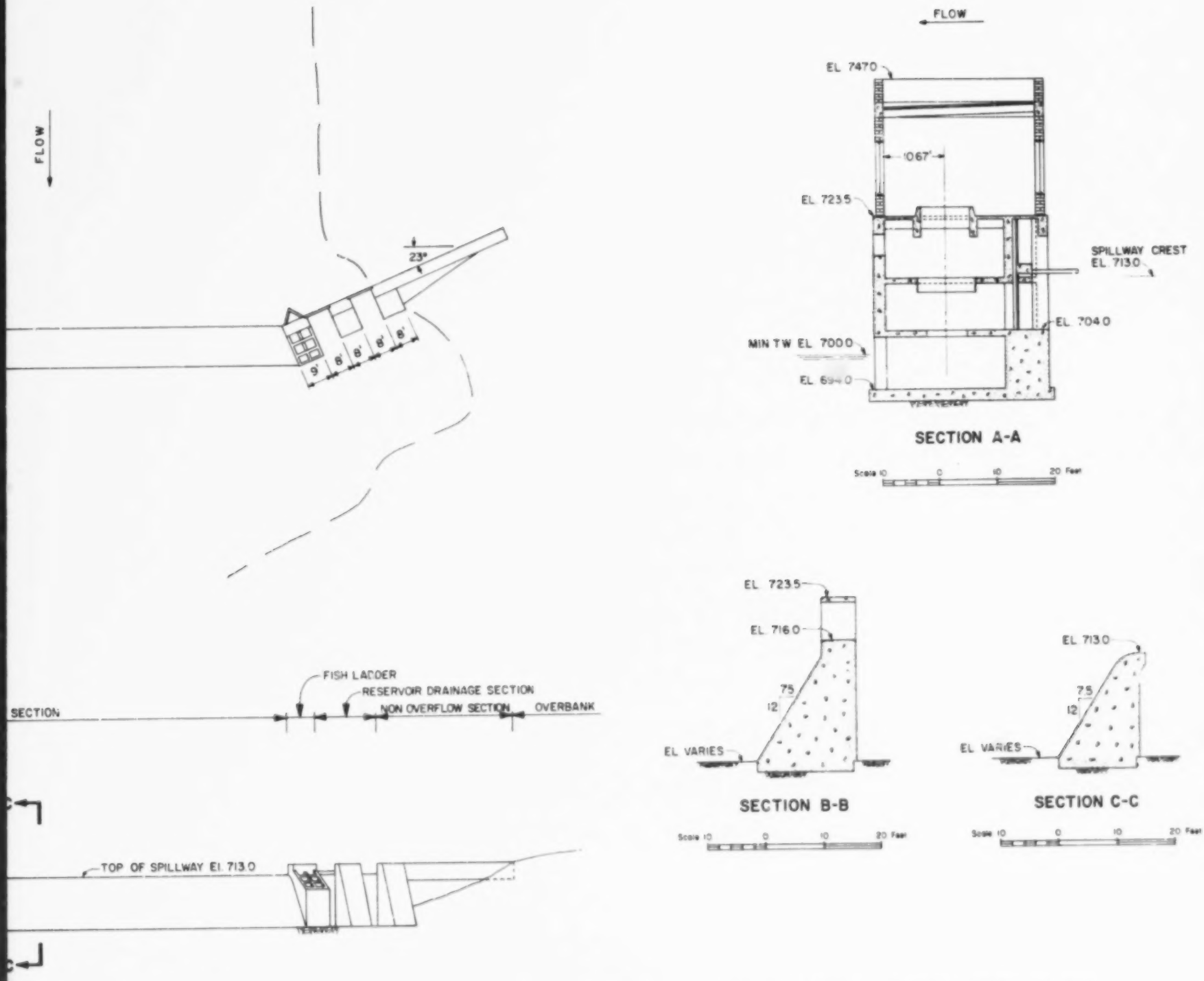

Figure 3 - Existing Facilities - Shelbyville Dam

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and the park located on the left bank is used for various recreational activities.

B. Dam

Shelbyville Dam is a concrete gravity structure having three distinct sections; the main dam, an east section, and a west section. The main dam is 201 feet long. One hundred and eighty-five feet of this length is a spillway section 18 feet high, 13.5 feet thick at the base, and has a crest elevation of 713.0. The west section of the dam, set at an angle of 23 degrees upstream, is similar in construction to the main dam. This section is approximately 85 feet in length with a top elevation of 716.0. It also contains a fish ladder and two sluices which are eight feet wide. The east section is 57 feet long, 14 feet high, and 12 feet thick at the base. It is built at a 30-degree angle upstream of the powerhouse and has a spillway crest elevation of 716.0. A walkway on top of this section at elevation 723.5 provides access to the powerhouse. The dam appears to be structurally sound with no major problems evident. Preliminary stability analysis of the dam indicates that it is safe from failure by overturning and sliding. It should also be noted that since its construction, the dam has withstood floods exceeding the 1-percent-chance (100-year flood).

C. Powerhouse

The original powerhouse is located on the east bank and is approximately 35 feet long and 21 feet wide. All electromechanical equipment has been removed and the powerhouse superstructure has been razed. The powerhouse being considered for rehabilitation was con-

structed in 1924 and is located at the east end of the main dam. It is constructed of reinforced concrete and brick and is approximately 45 feet long and 30 feet wide. Two turbines were installed on the second floor, and the upper floor contained two generators, governors, controls, and the electrical equipment. However, all this electromechanical equipment has been removed.

Water entered the powerhouse through six openings, each approximately 8 feet high and 4.75 feet wide and controlled by a concrete gate. Water exited the powerhouse through two openings, each approximately 9 feet high and 19.5 feet wide. Presently the intake area immediately upstream of the powerhouse is heavily silted.

The powerhouse appears to be structurally sound with no major problems evident. It is in need of cleaning, painting, replacement of windows, and an access door.

D. Substation and Transmission Lines

The Shelbyville substation is located approximately 250 feet southeast of the powerhouse. Three transmission lines of 46-kV pass within 0.1 mile of the site.

IV. HYDROLOGY AND HYDRAULICS

Land drained by the Upper Duck River is largely agricultural in use and totals 425 square miles at Shelbyville Dam. A small reservoir with no appreciable storage capacity is impounded by the dam and is used primarily for the city of Shelbyville's water supply. Withdrawal amounts to a very small fraction of the average flow. Precipitation in the watershed

above the dam averages 55 inches per year. The river, prior to regulation, had extreme variations in the amount of streamflow, ranging from frequent flooding in the winter months to poorly sustained flows in late summer and fall. Based on historical data from a streamgage located 5.2 miles downstream, the average flow at the dam is 730 cfs and the minimum daily flow is 18 cfs. Now, the minimum regulated flow is 166 cfs. The maximum known flood occurred March 29, 1902, and crested at elevation 737.3 at Shelbyville Dam.

With its 195 square mile drainage area, Normandy Dam controls the streamflow for 46 percent of the watershed above Shelbyville. The normal operation of Normandy Dam will tend to ease extreme flow conditions. A minimum flow of 166 cfs will be assured at Shelbyville for water quality and supply purposes. The regulated 100-year flood at Shelbyville Dam would be 46,500 cfs and would crest at elevation 734.0.

A flow duration curve was generated with flows obtained from a simulated operation of the Normandy Reservoir and the uncontrolled flow between Normandy Dam and Shelbyville Dam. The period of record used was 1921-1965. Figure 4 is the simulated duration of flow curve for the Duck River at Shelbyville Dam.

V. PROJECT DEVELOPMENT

In selecting the best redevelopment plan for the project, several alternatives were considered. Emphasis was placed on minimizing civil works, selecting a standardized turbine, choosing an installation similar in size to the original units, and ensuring that any adverse impacts on the environment be minimized.

To comply with these conditions, all alternatives would provide run-of-river operation of the hydroplant and would utilize the existing powerhouse. It was determined that the following three types of units would show the most promise of rendering a viable project:

1. Improved vertical Samson turbine manufactured by The James Leffel and Company
2. Vertical shaft Mini TUBE turbine manufactured by Allis-Chalmers
3. Vertical Francis Type Z turbine manufactured by The James Leffel and Company.

The installation selected as the best alternative for utilization at Shelbyville Dam is the 48-inch type Z turbine. This unit has a Francis runner and is primarily controlled by wicket gates located at the turbine inlet (Figure 5). It is designed to operate in an open flume setting which would be provided in the existing powerhouse. Placement would require few modifications to the turbine and generator floors.

A horizontal shaft generator rated at 230 kW would connect to the turbine through a speed increaser. Power produced would be fed to nearby transmission lines.

A one-unit installation was chosen rather than the original two-unit installation because of the streamflow pattern of the Duck River at Shelbyville Dam and because of economic reasons. This installation could operate continuously except for periods of extremely high streamflow and during times required for maintenance. The turbine would have the ability to utilize the streamflow pattern efficiently, including the regulated minimum flow of 166 cfs. It could be operated at a full gate opening 45 percent of the time and at a 50 percent gate opening for the regulated

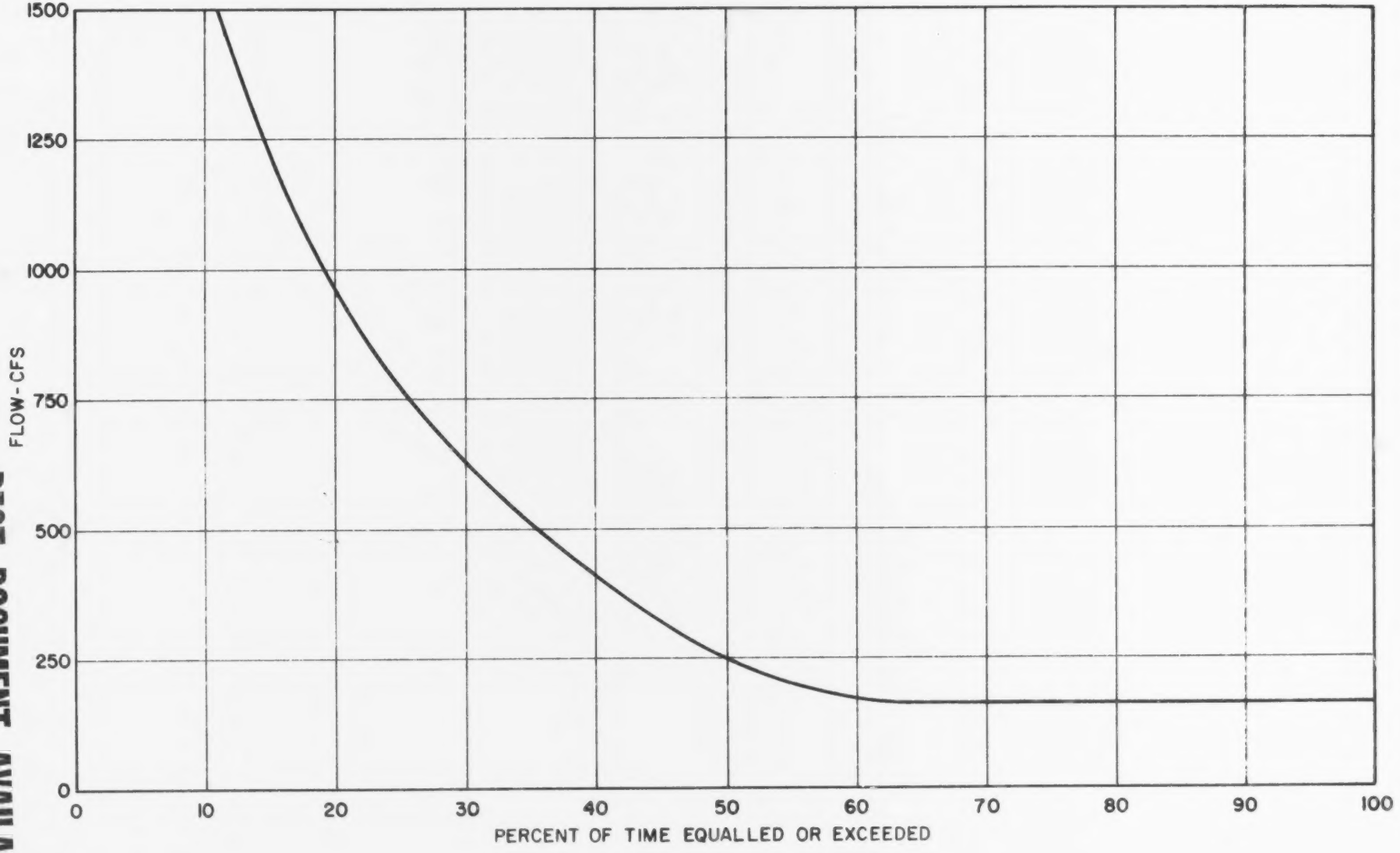

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Figure 4. Duration of Flow

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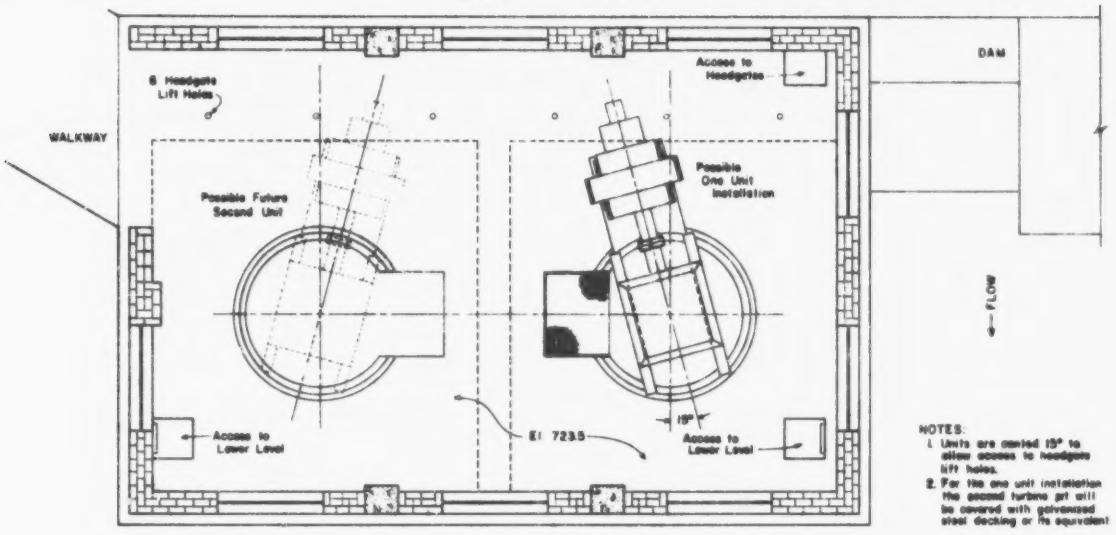
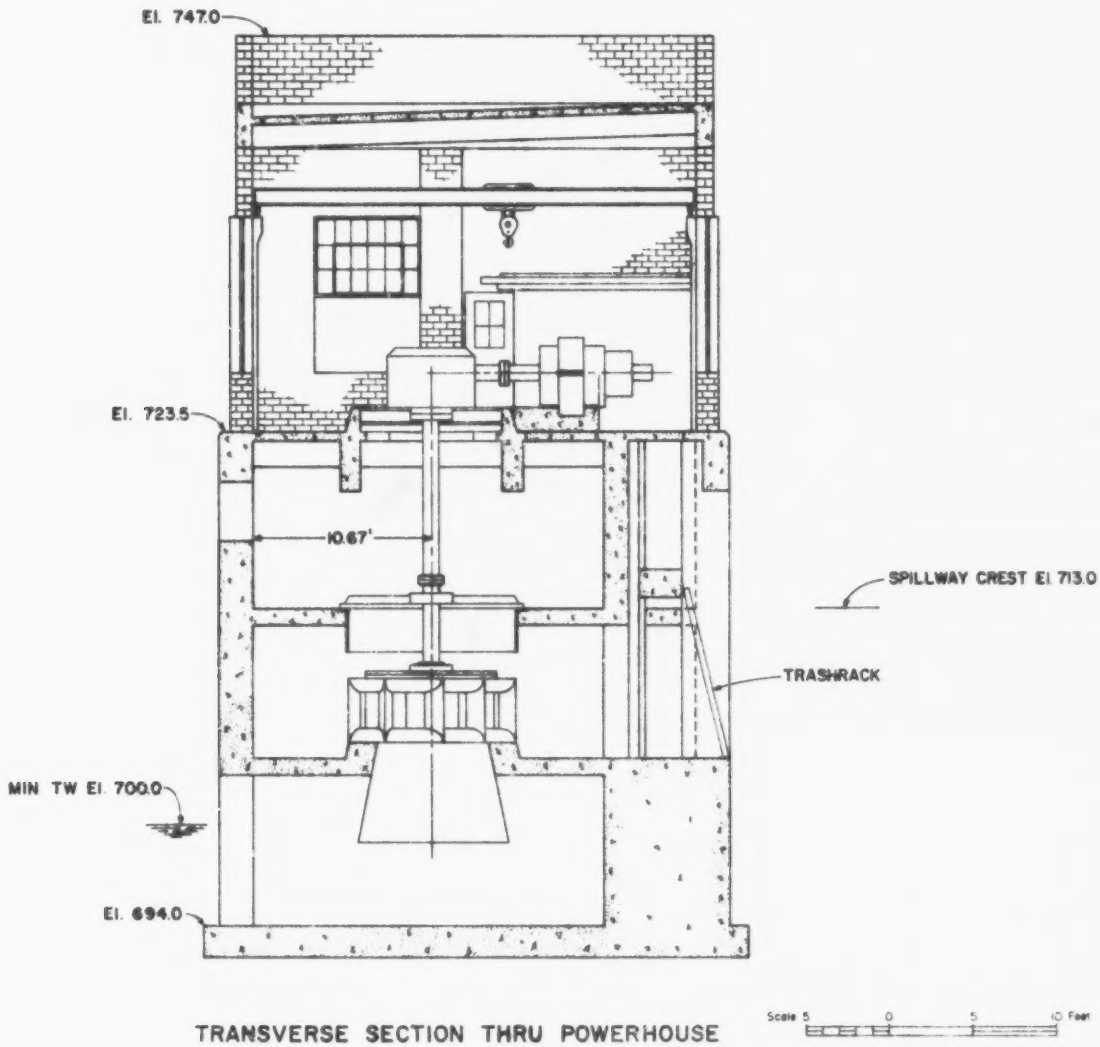

6 Headgate Lift Holes
WALKWAY
Possible Future Second Unit
Access to Headgates
Possible One Unit Installation
DAM
FLOW
Access to Lower Level
El. 723.5
Access to Lower Level
NOTES:
1. Units are canted 15° to allow access to headgate lift holes.
2. For the one unit installation the second turbine pit will be covered with galvanized steel decking or its equivalent

PLAN - GENERATOR FLOOR



TRANSVERSE SECTION THRU POWERHOUSE

Figure 5. Possible Redevelopment Plan - Shelbyville Dam

minimum flow which occurs 40 percent of the time. The unit would produce 1,300,000 kWh per year.

If a second unit with the same operating characteristics were installed, it could be operated only 50 percent of the time because of insufficient flow, and could be operated at a rated capacity only 30 percent of time. This unit would produce an additional 500,000 kWh per year. At present, the increase in average annual energy which could be produced by a second unit cannot justify the cost of the unit.

Although only a one-unit installation was chosen at the present time, provisions were made to facilitate the addition of a second unit if the economics can justify it in the future. The area behind the undeveloped unit would be desilted and the existing intake gates would be replaced. These tasks could be accomplished while the cofferdam is in place and the area behind the powerhouse is dewatered for work on the other unit. This would add little cost to the one-unit installation and would save much time and money should this work need to be done in the future.

Access to the powerhouse area would be provided by a new road constructed at the east abutment of the dam (see Figure 6). This road would be approximately 260 feet in length and would permit delivery of equipment and personnel.

Major construction items include:

1. Powerhouse renovation
2. Replace trashrack and intake gates
3. Remove silt behind powerhouse
4. Build an access road
5. Install necessary mechanical and electrical equipment.

Diversion and care of water would be accomplished by a sheet steel cofferdam upstream of the powerhouse and a temporary bulkhead covering the draft tube exit.

Normal operation of the plant would be unmanned with manual startup and automatic shutdown. Sufficient cover on the existing water supply intake would be assured by installing automatic headwater level control equipment which would limit reservoir fluctuation to less than one foot below top of dam.

The remaining portion of the original powerhouse is an open foundation approximately 35 feet long, 21 feet wide, and 20 feet deep. To prevent this structure from being a safety hazard it should be covered with concrete.

VI. POWER PRODUCTION

It is assumed that operation of the possible hydroplant would be run-of-river. The potential power was determined utilizing the duration of flow curve shown in Figure 4. Usable flow under the curve was divided into several increments and average annual generation was computed by summing the potential energy from each increment under the curve. For this computation, a specific efficiency value was assigned to each increment of flow based on manufacturer's unit performance curves and net heads were computed using a tailwater curve and accounting for losses in the system.

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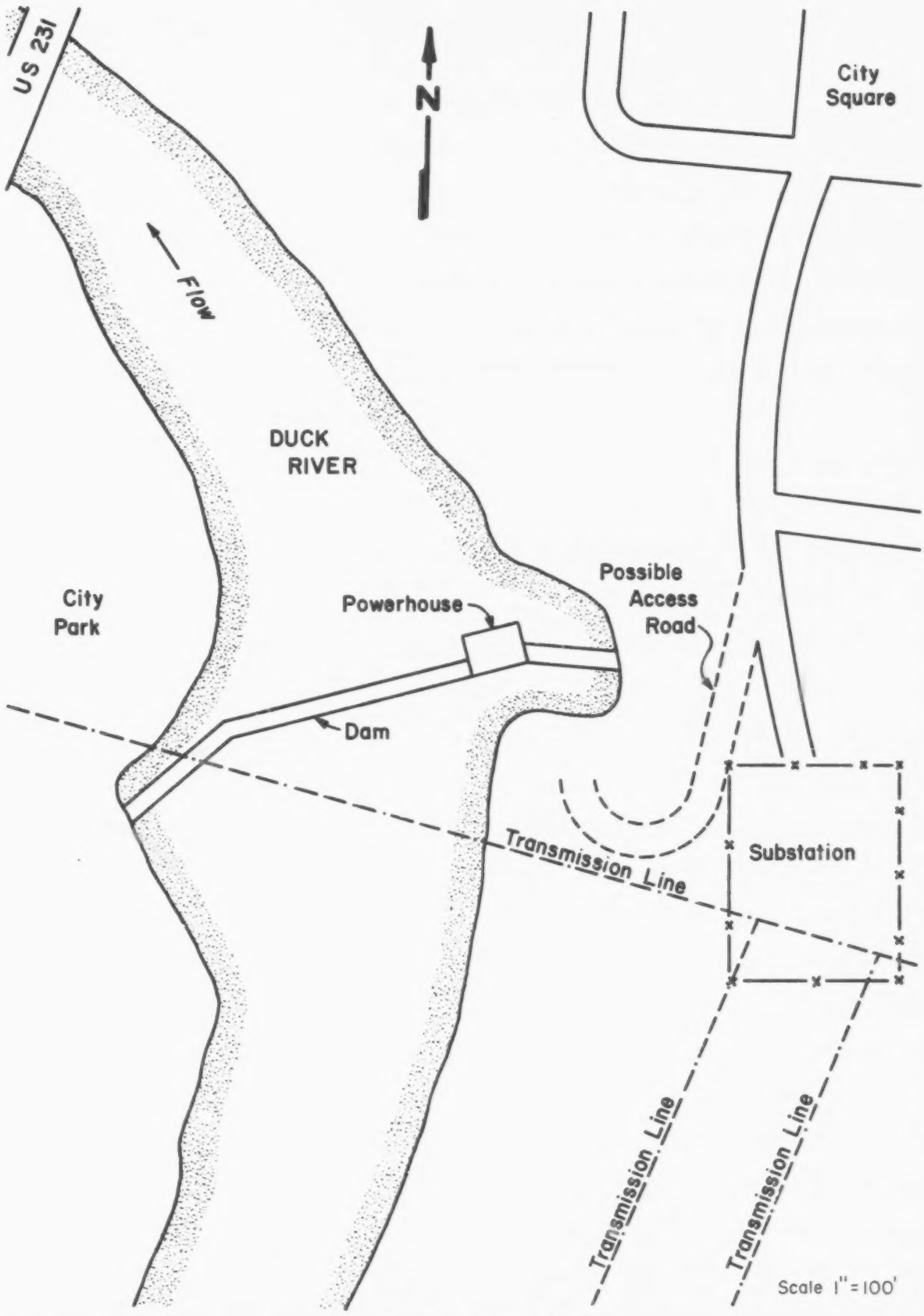

Figure 6. Possible Site Plan

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IX. ECONOMIC ANALYSIS

The feasibility of restoring the hydro facilities at Shelbyville Dam was evaluated by comparing the present worth of the project's benefits and costs over an assumed 35-year economic life of the project to form a benefit-cost (B/C) ratio. Benefits are based entirely on the amount of energy supplied to the local transmission system. Project costs are comprised of the capital cost of the rehabilitation work and the present worth of operation and maintenance costs. For the city of Shelbyville, the most likely developer, a discount rate of 10 percent was assumed since this is the approximate municipal bond rate.

The present worth of power benefits and operation and maintenance costs was computed for two different economic forecasts. An escalation rate of 10.5 percent was assumed for the first eleven years in the high forecast and 10.0 percent for the remainder of the economic life. In the low forecast 7.3 percent escalation was assumed for the first 11 years, 5.5 percent for the next 8 years, and 6.0 percent for the last 16 years.

SHELBYVILLE DAM

HYDROELECTRIC PLANT REHABILITATION

Estimate of Cost[1]

General Yard Improvements	$ 12,000
Powerhouse	12,000
Reservoir	5,000
Intake	18,000
Turbine-Generator Equipment	408,000
Electrical Equipment	63,000
Cranes and Hoisting Equipment	15,000
Construction Facilities	67,000
Total Direct Construction	600,000
Field General Expense	42,000
Contingency	74,000
Total Field Construction	716,000
Interest During Construction	50,000
Total Construction	766,000
Engineering Design	90,000
Administration	34,000
Total Construction	$890,000

[1]Total project cost is based on 1981 dollars. This estimate does not include the primary reclosure and the 13.2 kV/480-volt transformer (usually furnished by the utility).

Figure 7: Cost Estimate

The present worth of the project benefits and costs for the high forecast equals $1,465,000 and $1,221,000, respectively, resulting in a B/C ratio of 1.20. The low forecast present worth values for project benefits and costs are $868,000 and $1,086,000, respectively, which yield a B/C ratio of 0.80. Since actual values are expected to fall in between these numbers, this analysis is not sufficient to make a decision on implementation. A potential developer would need to perform a detailed financial analysis to determine if he could utilize available tax benefits from the project to produce a satisfactory return on investment.

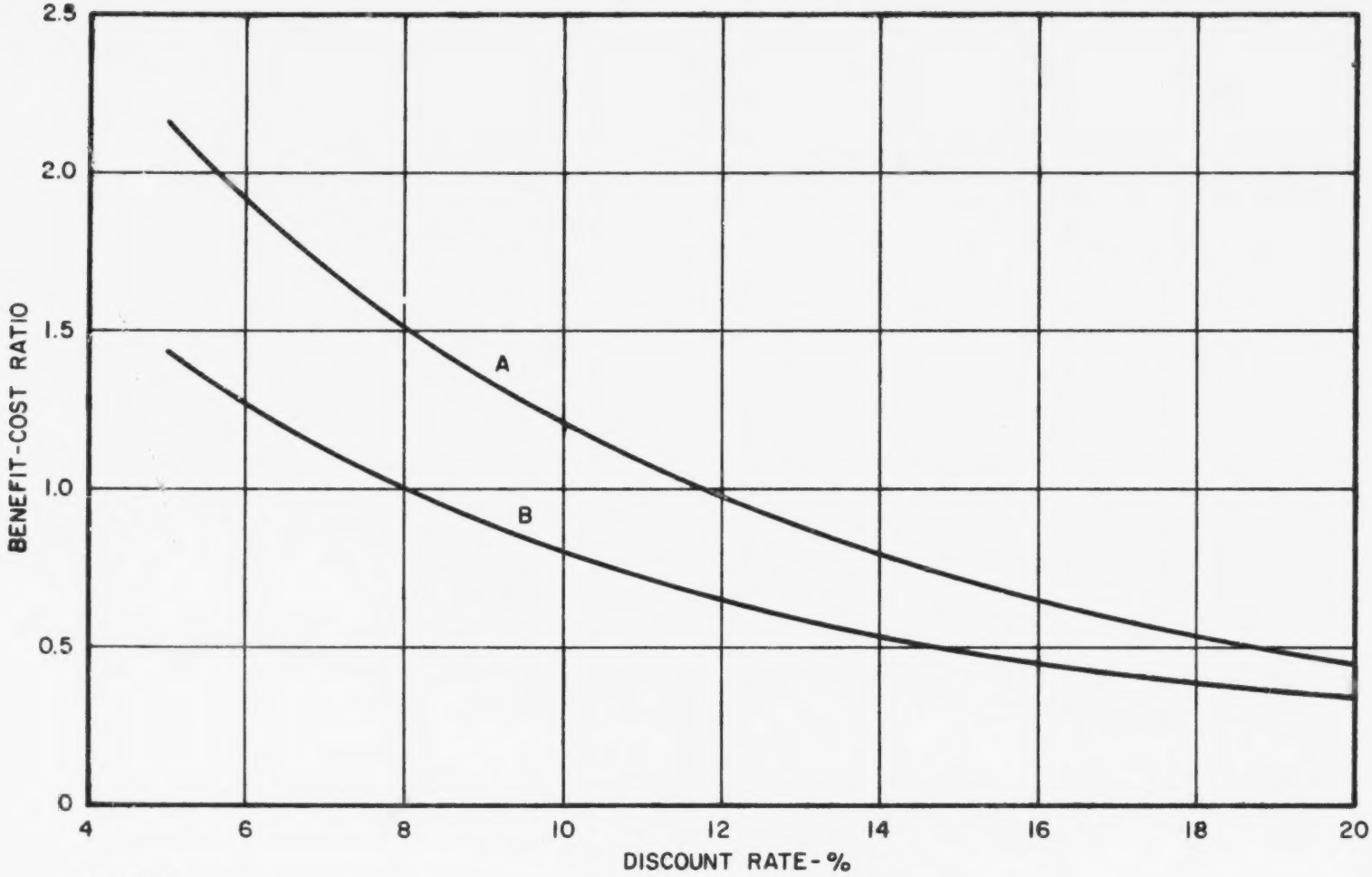
Figure 8 shows the sensitivity of the B/C ratio to varying discount and escalation rates assuming a 35-year economic life. The B/C ratio can be significantly affected by a different prediction of the future state of the economy, a different applicable discount rate, and reduction in the total project cost.

X. ENVIRONMENTAL ASSESSMENT

The environmental effects of hydro projects, which have relatively small existing dams and operate as run-of-river plants, are most often minimal. This concept is consistent with independent studies made by several organizations. One such study was done by a consultant for assisting the Federal Energy Regulatory Commission (FERC) in proposing regulations to exempt certain projects from licensing as provided in Part I of the Federal Power Act. To qualify for such exemption, a candidate must be an existing dam, have a total installed capacity of less than 5 MW, and meet the following conditions:

1. Repair or reconstruction of the dam must not raise the normal maximum surface elevation of the impoundment.
2. There must not be significant existing upstream or downstream passage of fish.
3. Operation of the dam for hydropower purposes must not change the normal storage and release pattern of the impoundment.
4. The discharge from the powerhouse must be located no more than 300 feet from the toe of the dam.
5. The project must not involve construction at or alteration of a historic site.
6. If the project requires a new transmission line, it must be 69 kV or less, and the line must be shorter than one mile if located on a new right-of-way.
7. The project must not adversely affect a Federally-designated critical habitat or a Federally designated threatened or endangered species.
8. The project must not cause violations of applicable State or Federal water quality standards.

The possible redevelopment of the Shelbyville Dam meets all of the above conditions. Therefore, it is anticipated that long term environmental effects would not be a significant deterrent to the rehabilitation. Short term environmental effects caused by the construction, such as an increase in the turbidity of the water and construction noise, would be minimized by proper construction techniques and would be only temporary.



LEGEND:

A High escalation rate for benefits and O&M costs

B Low escalation rate for benefits and O&M costs

Figure 8. Discount Rate vs. Benefit-Cost Ratio

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XI. CONCLUSIONS AND RECOMMENDATIONS

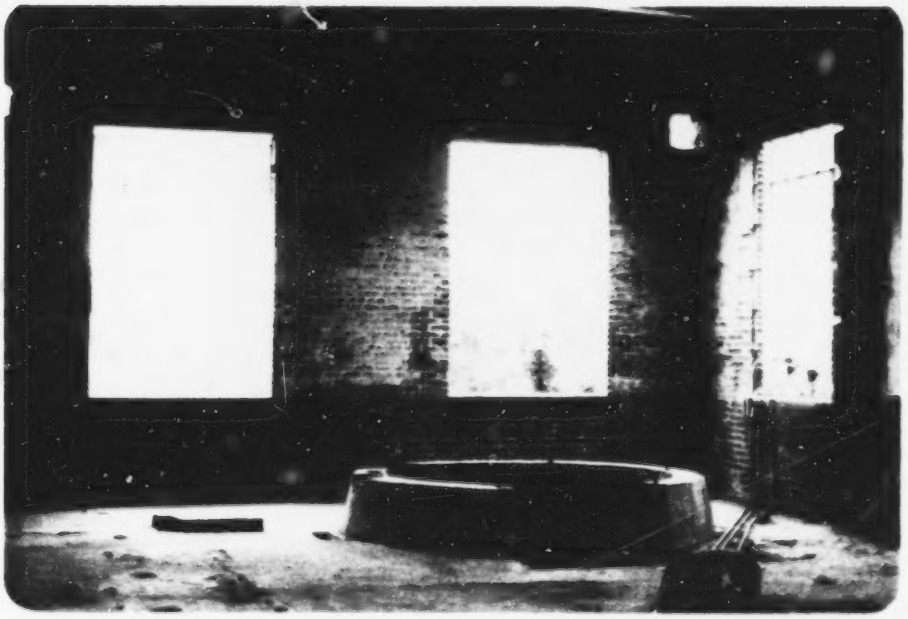
Based on the analysis made in this study, the feasibility of restoring the power facilities at Shelbyville Dam would be marginal. Depending upon the economic forecast assumed, the Benefit-Cost ratio ranges between 0.80 and 1.20 at a 10 percent discount rate.

Favorable economics would depend on the developer's ability to reduce costs, his ability to secure low interest financing, and his financial situation being such that he could take advantage of tax benefits available to small hydro investors.

There are also some disadvantages to be considered. The developer should be aware that there could be negative cash flows for the first several years of operation until escalating benefits reach and surpass costs. The possibility of damage to the generator and electrical equipment due to flooding exists. In the past this location has been vulnerable to frequent flooding. Even with the presence of Normandy Dam which reduces flood damages downstream of it, the possibility of equipment replacement and repair remains.

If the developer can meet the above conditions and is willing to take the associated risks, it is recommended that a detailed financial analysis be performed. A decision on whether or not to proceed with redevelopment can then be made.

Downstream view of powerhouse and dam.



Interior view of powerhouse.

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APPENDIX H

SHOAL CREEK NO. 1 DAM

APPENDIX H

FEASIBILITY REPORT - SHOAL CREEK NO. 1 DAM

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SUMMARY OF PRINCIPAL FEATURES

Shoal Creek No. 1 Dam

Location

On Shoal Creek in Lawrence County, Tennessee, about 1.8 miles southwest of Lawrenceburg.

Owner

City of Lawrenceburg

Streamflow

Drainage area	75 sq. miles
Average discharge	142 cfs

Tailwater

Normal operating	El. 743.6
Minimum	El. 742.5

Operating Heads (net)

Maximum	36.8 ft
Minimum	32.2 ft
Rated	34.0 ft

Dam

Type	concrete spillway and earth embankment
Length	402 ft
Height	20 ft
Top of spillway	El. 780.1

Possible Power Facilities

Type	prefabricated hydroelectric generating station
Hydraulic turbines	
Number	one
Type	Francis, vertical shaft
Runner diameter	1000 mm (39.4 in)
Generator	
Type	induction
Rating	300 kW
Plant output	
Average annual energy	1,100,000 kWh
Existing intake tunnel	250 feet in length

Cost

Total project cost	$1,180,000
Cost per kW	$3,900

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SUMMARY

This report presents the results of a study to determine the merits of restoring hydroelectric generating facilities at the Shoal Creek No. 1 site, which is an abandoned hydroelectric plant near Lawrenceburg, Tennessee. The costs used for this report reflect construction costs experienced by TVA including overheads normally used in TVA accounting procedures. A developer may possibly achieve cost savings if he has the capability of furnishing labor and materials at lower costs and if he can obtain financing at a lower discount rate.

The evaluation of several alternative plans using TVA costs and benefits and an assumed discount rate indicates that the redevelopment of the Shoal Creek No. 1 Dam is not currently economically feasible.

I. INTRODUCTION

The purpose of this report is to investigate the possibility of restoring hydroelectric power generation facilities at the Shoal Creek No. 1 Dam on Shoal Creek near the city of Lawrenceburg, Tennessee.

TVA's Small Hydro Program is divided into reconnaissance and feasibility stages. The purpose of the program is to investigate the potential for small scale hydroelectric production in the Tennessee Valley Region. The first phase, which was completed in June 1980, consists of an inventory and reconnaissance level screening of existing non-Federal dams in the Tennessee Valley and the TVA power service area. Out of this reconnaissance phase, ten of the more promising sites, of which the Shoal Creek No. 1 Dam is one, were selected for detailed feasibility studies.

The current enthusiasm for small hydropower as a clean and renewable energy source must be balanced by a recognition that the feasibility of small hydro projects is especially sensitive to the costs of electrical generation from other sources and to the costs of borrowing capital. No venture is attractive unless it offers a satisfactory return on investment. In this study, the primary tool for determining the merits of restoring the Shoal Creek No. 1 site is an economic analysis of project costs and benefits.

II. SITE HISTORY AND DESCRIPTION

The Shoal Creek No. 1 site consists of a dam, tunnel, and powerhouse located in Horseshoe Bend on Shoal Creek in Lawrence County,

Tennessee, about 1.8 miles southwest of the city of Lawrenceburg (see Figures 1 and 2). The site is reached by secondary roads from Lawrenceburg and an unpaved farm road. The city of Lawrenceburg owns the site which formerly supplied power to the city.

The city of Lawrenceburg built two hydroelectric plants on Shoal Creek. Shoal Creek No. 1, built in 1907, was unable to meet the city's demand for long and a second plant, Shoal Creek No. 2, was built about 1.8 miles downstream in 1915. When the Tennessee Valley Authority began supplying power to the area in 1939, these two plants were still supplying a portion of the city's needs. In the forties the city ceased operation of the Shoal Creek No. 1 Plant and the second plant was abandoned a few years later.

As shown in Figure 3, the Shoal Creek No. 1 plant is situated on a sharp bend in Shoal Creek in order to take advantage of the 17-foot fall between the dam and the powerhouse. Water impounded behind the dam was diverted across the bend through a tunnel to the powerhouse and then returned to the creek. Presently the low flow of Shoal Creek is diverted through the tunnel and spills into the abandoned powerhouse.

The dam consists of a concrete spillway section and an earthen nonoverflow section. The trapezoidal spillway section is about 200 feet long and is founded on limestone bedrock. A low-level sluice closed with a wooden bulkhead extends through this section. The concrete spillway is in good condition exhibiting only normal surface weathering. The earthen portion of the dam extends about 200 feet from a wing wall on the right side of the spillway. The embankment is heavily overgrown with trees and underbrush which is undesirable for an embankment which constantly impounds water, but in the case of Shoal Creek No. 1 only high flows of

Figure I. Location Map

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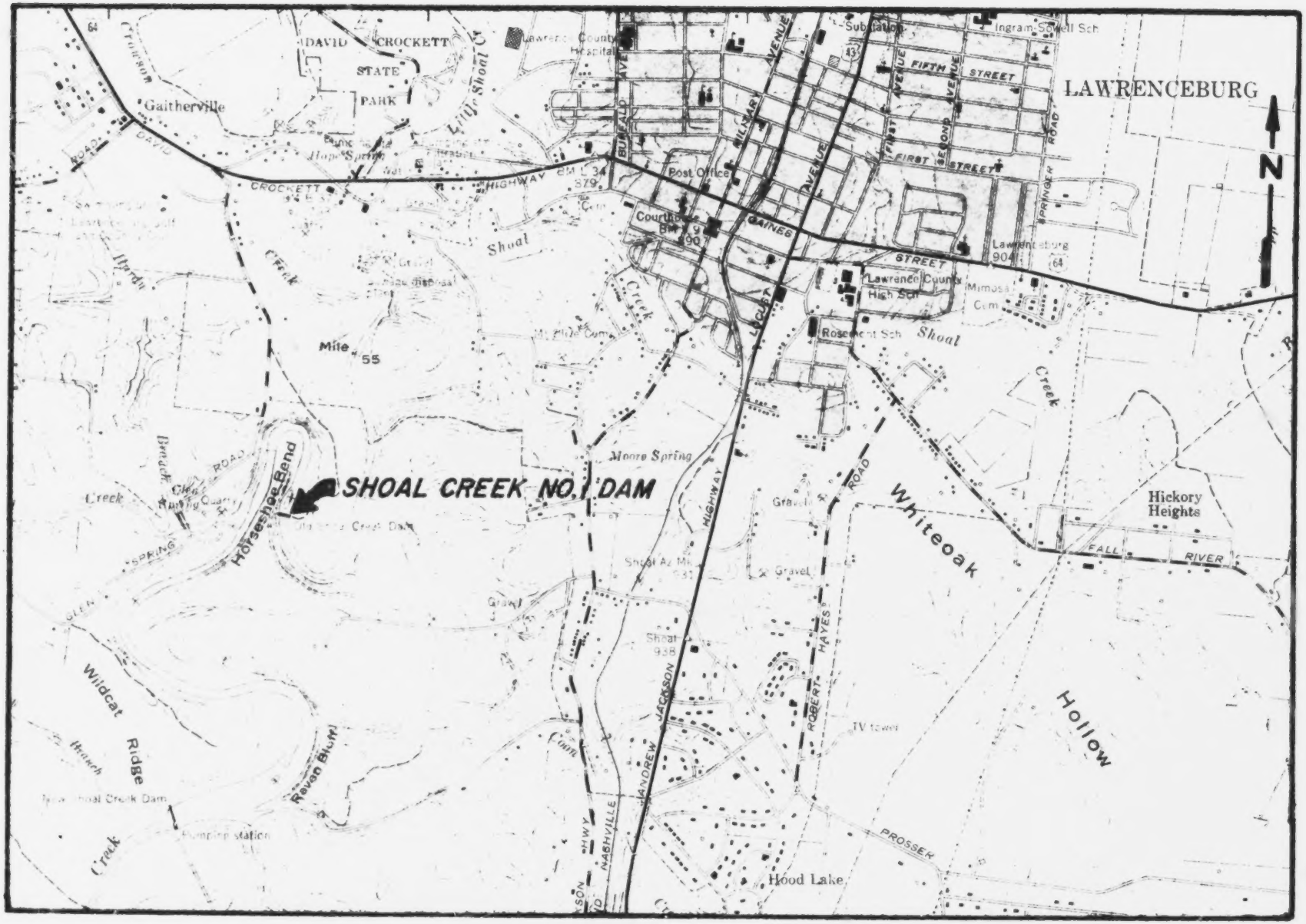

Figure 2. Vicinity Map

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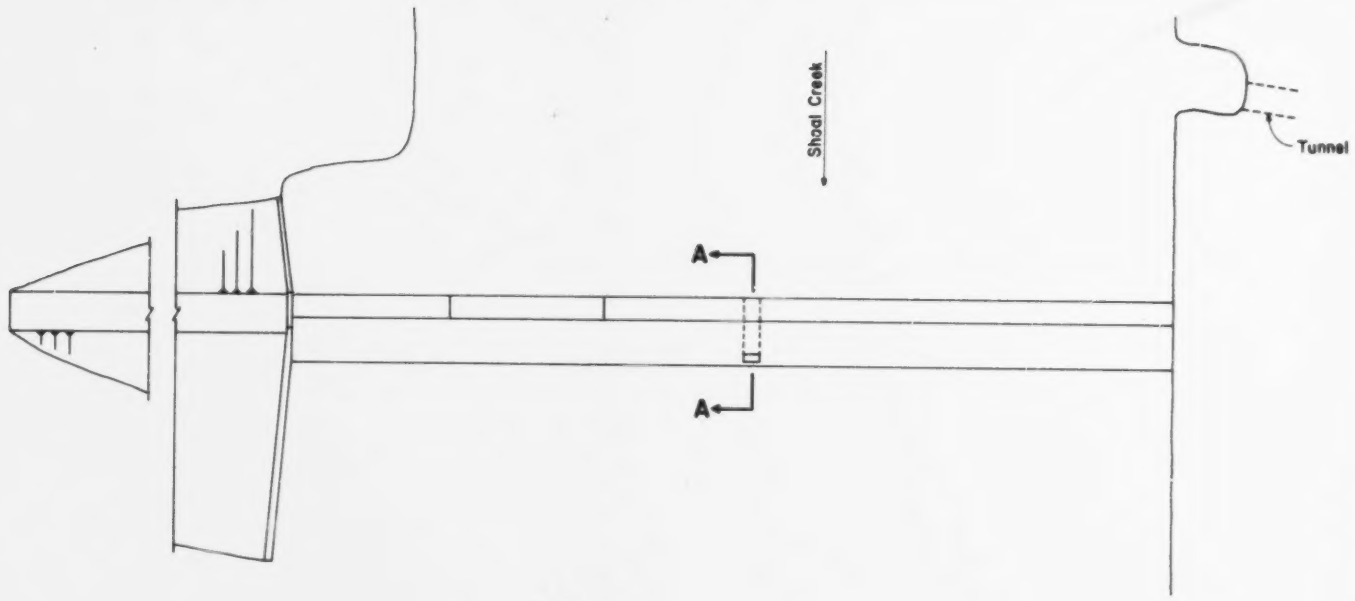

PLAN-DAM

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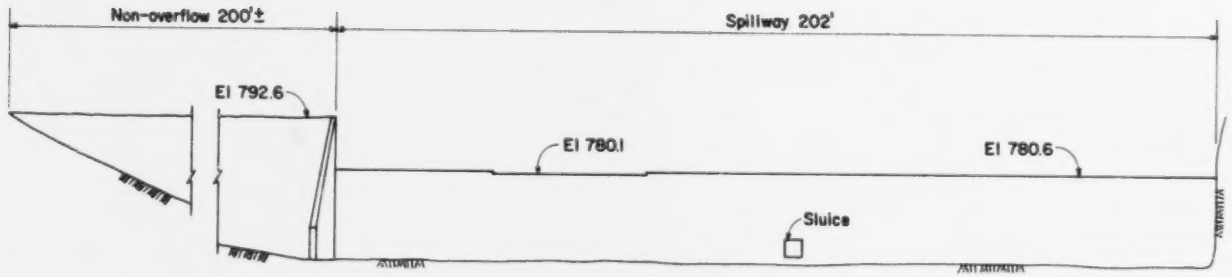

DOWNSTREAM ELEVATION – DAM

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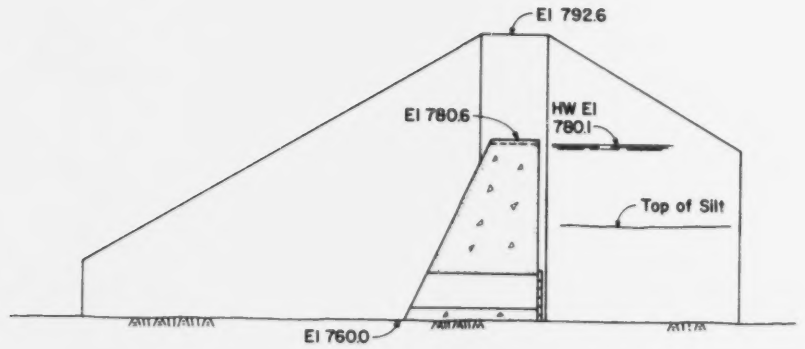

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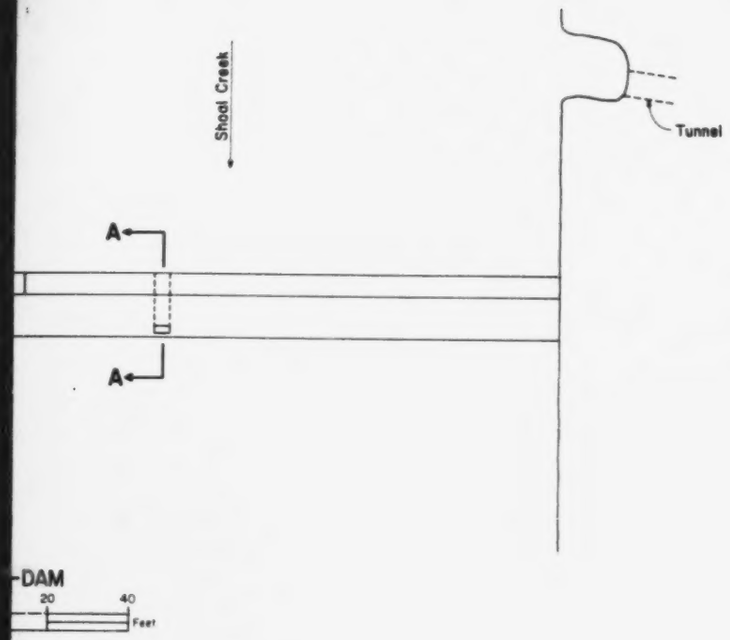

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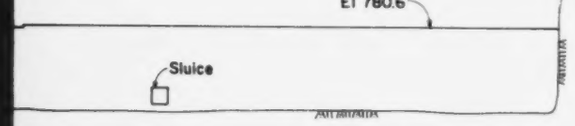
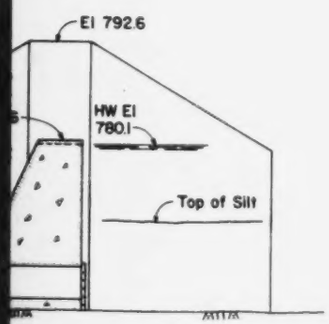


EVATION – DAM

20 40 Feet



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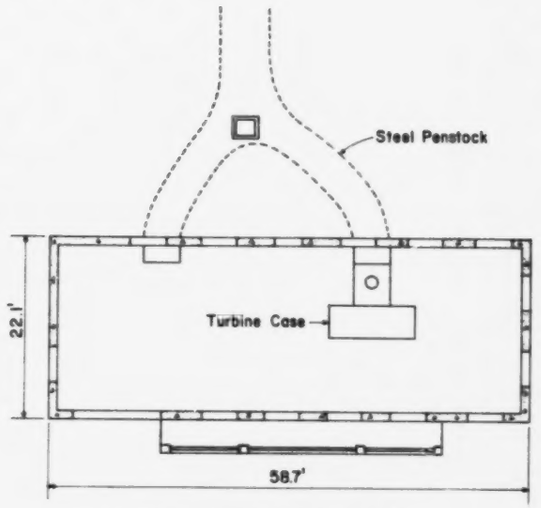

PLAN-POWERHOUSE FLOOR

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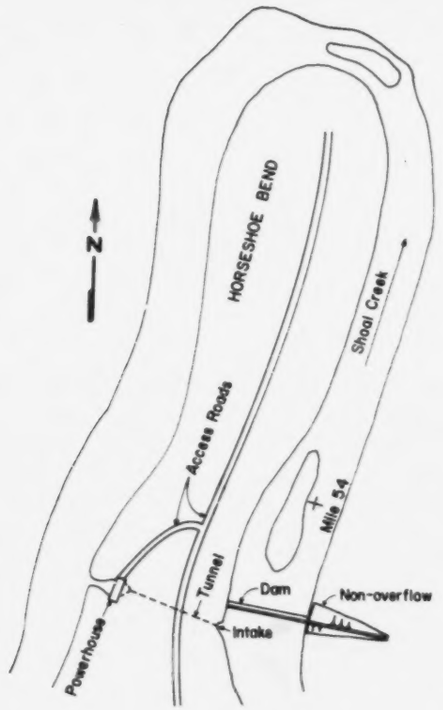

SITE PLAN

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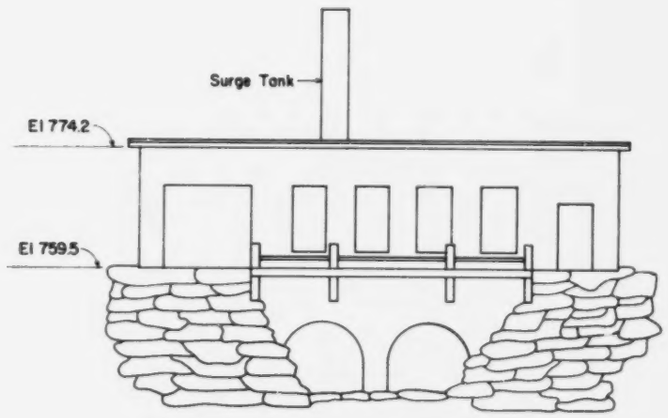

DOWNSTREAM ELEVATION-POWERHOUSE

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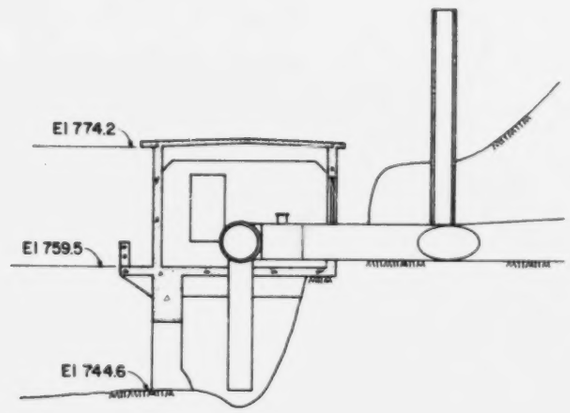

SECTION THRU POWERHOUSE

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Figure 3. Existing Facilities-Shoal Creek No.1 Dam

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short duration reach the earthen section. There is very slight leakage emerging at the wing wall, but this does not appear hazardous. Overall both the embankment and spillway are in good condition.

Preliminary stability analysis of the concrete spillway indicates that, while the spillway is stable during normal loading conditions, during extreme flow periods the spillway is not stable against overturning using current standards and design assumptions for uplift under the dam. Failure of the dam would pose little downstream hazard but would destroy the ability to produce power at the site.

The reservoir behind the dam extends about 1.6 miles upstream and has a volume of approximately 200 acre-feet of which about one half is accumulated silt. Presently the reservoir has no specific use.

The entrance to the power tunnel is about 50 feet upstream of the left abutment of the dam. There is no evidence of the original trash-racks and intake structure. The tunnel is probably unlined, but this has not been verified by inspection. The minimum practical construction diameter would be about six feet. The tunnel splits about 200 feet below the entrance into two badly corroded steel penstocks which enter the powerhouse. The tunnel is open and conducts water onto the floor of the powerhouse.

The powerhouse is a reinforced concrete structure situated on a steep bank above the creek. A single floor 22 feet by 57 feet supported the turbines, generators, and other equipment. The walls and roof are in good condition, but the floor and substructure have been severely damaged by the water flooding the powerhouse. Windows, doors, and other fixtures have all been removed. Overall, the condition of the structure is poor.

Originally there were two horizontal Francis turbines developing 600 horsepower under a 37-foot gross head at the Shoal Creek No. 1 plant. These turbines received water from the penstocks and discharged water through the draft tubes directly underneath the powerhouse. The turbines, generators, and other equipment were removed when the plant was retired.

III. HYDROLOGY AND HYDRAULICS

Shoal Creek at the Shoal Creek No. 1 Dam drains a 75-square mile watershed devoted primarily to agricultural use. Annual precipitation in the area averages about 55 inches. Based on records available for Shoal Creek the average annual flow at the site is 142 cfs and the 7-day, 10-year low flow is about 17 cfs.

Figure 4 is the duration of flow curve for Shoal Creek at the Shoal Creek No. 1 Dam based on adjusted streamflow records from the USGS stream gage on Shoal Creek at Iron City, Tennessee. These adjusted flows are based on the drainage area ratio of 75 square miles at the site to 348 square miles at Iron City. The period of record is the 48-year period from 1926 to 1973. There is a USGS gage on Shoal Creek at Lawrenceburg having a drainage area more nearly equal to that at the Shoal Creek No. 1 plant, but these records were not used because the period of record is from 1968 to 1979 which is a wetter than average period.

In light of the low hazard potential and low investment cost of the Shoal Creek No. 1 project relative to a large hydroelectric facility, the 100-year flood was selected as the design flood for this study. Based on

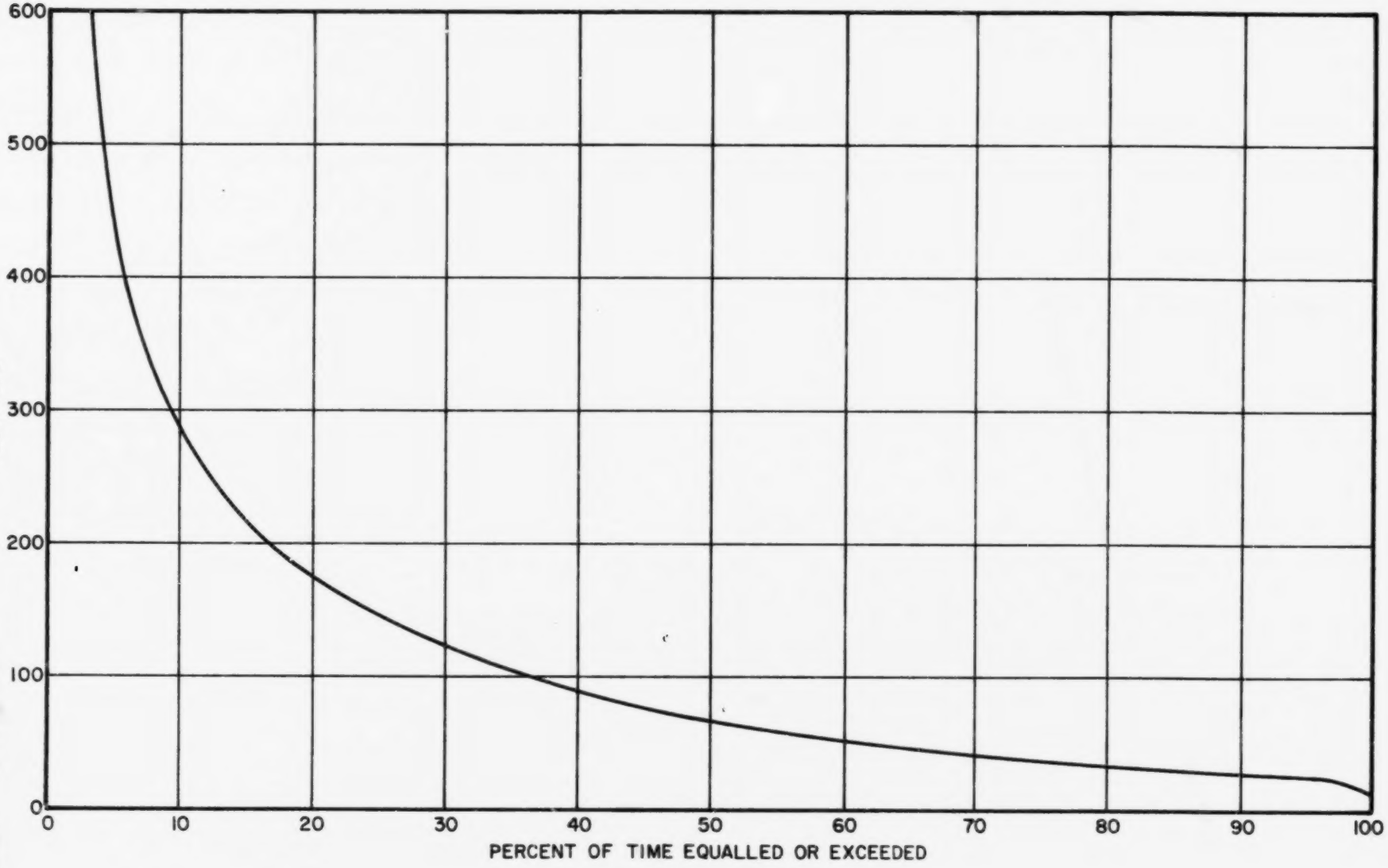

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Figure 4. Duration of Flow

flood studies done at Lawrenceburg by TVA, the 100-year flood on Shoal Creek at the site is approximately 20,000 cfs. Unlike many older dams, the concrete spillway section can pass the 100-year flow without overtopping of the nonoverflow section. It may be that the original designers were aware of the large flood of March 1902 which had a return period somewhat greater than 100 years.

IV. PROJECT DEVELOPMENT

Since much of the original power installation is in such poor condition as to be unusable, there are many possible redevelopment schemes and the best scheme is not immediately obvious. The procedure to select the most cost effective scheme consists of studying various turbine installations and comparing their costs to their energy production. Redevelopment of the Shoal Creek site would have little, if any, capacity benefit.

A large portion of the work required for any redevelopment of the Shoal Creek No. 1 site is common to all schemes. This work consists of improvement of access into the site, silt removal from the reservoir, construction of an intake structure, tunnel inspection and cleanup, new penstock, and transmission facilities. For the alternatives studied, this work comprises about 30 percent of the total construction cost.

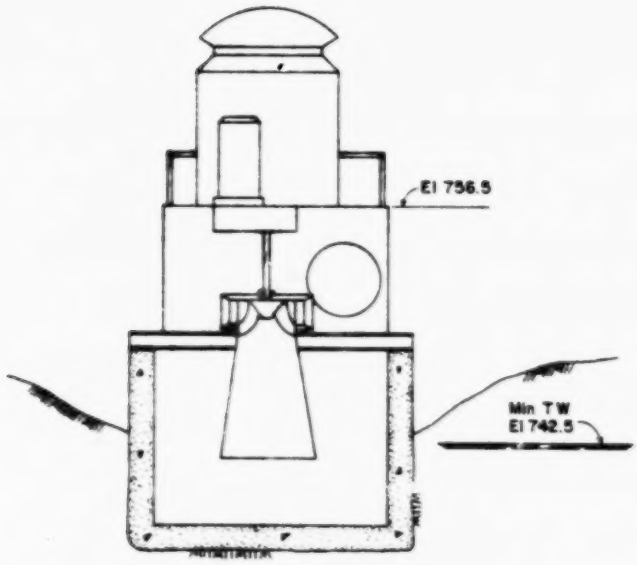
Three alternative turbine configurations were considered in addition to the scheme which was found to be the most cost effective. The first alternative studied was the installation of two horizontal Francis turbines in the existing powerhouse, but this alternative was ruled out because of the extremely poor condition of the existing powerhouse which

would necessitate expensive repair and because of the high cost of the two-unit installation. Various capacity horizontal axial flow (TUBE) and crossflow turbines located in a new powerhouse immediately below the existing powerhouse were also considered. These units achieved annual energy production greater than the prefabricated hydroelectric station which was finally selected, but the powerhouse structures required for the TUBE and crossflow turbines were too expensive in relation to the additional energy production.

The most feasible alternative appears to be a prefabricated Mini-Hydel hydroelectric station manufactured by Barber Hydraulic Turbine Ltd. This installation, shown in Figure 5, offers significant reduction of onsite costs because the station is factory assembled and shipped as a unit to the site where it is erected on a simple concrete foundation. The station utilizes a standardized vertical Francis runner in a steel structure with all other equipment located in a waterproof room above the turbine.

Three different capacity stations were considered to optimize energy production at the Shoal Creek No. 1 site. The highest average annual energy production was obtained from a 1000 mm (39.4 in) diameter runner developing approximately 300 kW under a 34-foot net head.

The Mini-Hydel station would feature manual startup and automatic shutdown; normal operation would be unmanned. All necessary controls and instrumentation are contained in the station. The induction generator, which takes its frequency and voltage regulation from the power grid, eliminates many of the problems of interfacing a small generator with a large distribution system. A gate operator and constant head monitor would be installed to prevent drawing of the reservoir during periods of reduced flow. The cost estimate for developing the Shoal Creek



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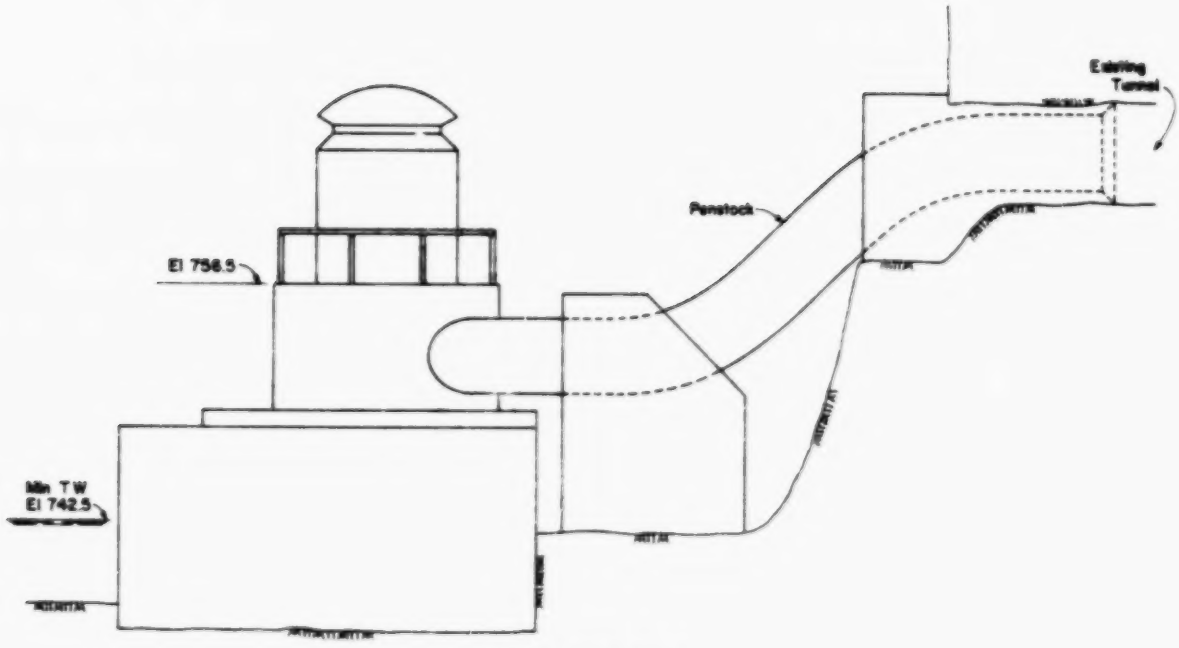
DOWNSTREAM ELEVATION



SIDE ELEVATION

Figure 5. Possible Power Installation-Shoal Creek No.1 Dam

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No. 1 site utilizing the Mini-Hydel station is included under the section on project costs.

V. POWER PRODUCTION

Since the storage in the reservoir behind the Shoal Creek No. 1 Dam is limited, operation of the project was assumed to be run-of-river. The average annual power production for each of the various turbine installations studied was estimated using the flow duration curve, Figure 4. Each block of usable flow under the curve was converted into an energy value using the average head and plant efficiency corresponding to the midpoint of each block. Plant efficiency was assumed to be a function of flow and turbine type with speed increaser and generator losses assumed constant. The average head was a function of streamflow and hydraulic losses. For the alternatives studied, average annual energy production ranged from 900,000 kWh to 1,400,000 kWh.

The average annual energy production of the Mini-Hydel station which has been selected as the most feasible alternative is estimated to be 1,100,000 kWh. The full gate output is approximately 300 kW and the average output over the period of the year when the plant would be operating is 240 kW. Power generation would not be continuous because approximately 40 percent of the time there would not be sufficient flow to operate the plant. Some operation would be possible during this period by using the available pondage, but this has not been taken into account.

VI. PROJECT BENEFITS

Redevelopment of the Shoal Creek No. 1 site would produce electrical energy either for the developer's own use or for sale under TVA's dispersed power production program which encourages energy production from renewable sources as called for by the Public Utilities Regulatory Policies Act of 1978 (PURPA). The program's rates, which are based on the wholesale rates which TVA charges its local distributors, are used in this study to evaluate energy production.

Under the program's present rate structure for plants having 100 kW or greater capacity, the price for onpeak electricity is 4.489 cents per kWh and 2.826 cents for offpeak electricity. Since plant operation at Shoal Creek No. 1 would use the available inflow without regard to the time of day, the weighted average of these two rates, 3.407 cents per kWh, has been used to evaluate the energy production. Using this value, the average annual energy production of 1,100,000 kWh is worth approximately $37,500. The energy value is subject to change in accordance with the adjustment provisions of TVA's wholesale power contracts.

VII. PROJECT COSTS

The estimated cost of redevelopment is $1,180,000 in 1981 dollars and includes the direct construction costs and allowances for design, administration, and contingencies. A summary of these costs is presented in Figure 6. The manufacturer supplied the cost of the prefabricated station and other costs are based on TVA's estimated costs. Attempts have been made to be as realistic as the level of study permits and to

SHOAL CREEK NO. 1 DAM

HYDROELECTRIC PLANT REHABILITATION

Estimate of Cost[1]

General Yard Improvements	$ 60,000
Powerhouse	64,000
Reservoir	79,000
Intake	60,000
Water Conductors	45,000
Generating Equipment (Includes Turbine and Generator)	400,000
Construction Facilities	89,000
Total Direct Construction	797,000
Field General Expense	56,000
Contingency	96,000
Total Field Construction	949,000
Interest During Construction	66,000
Total Construction	1,015,000
Engineering Design	120,000
Administration	45,000
Total Project	$1,180,000

[1]Total project cost is based on 1981 dollars. This estimate does not include the primary reclosure or the 13.2 kV to 480 V transformer.

Figure 6: Cost Estimate

include those items necessary for long term plant operation. It should be recognized that these costs are based on TVA's experience on similar work at larger projects which may not be applicable to all developers.

Operation and maintenance expenditures are estimated to be $10,000/year in 1981 dollars. This figure is based on judgment and operating expenses at other small hydro sites. The effects of various inflation rates on the operation and maintenance expenses are included in the economic analysis.

VIII. ECONOMIC ANALYSIS

The economic analysis of project costs and benefits provides a framework for deciding if a project development should proceed. For this study, the benefit-cost ratio method which compares as a simple decimal ratio the expected benefits and costs of redevelopment is used to determine economic feasibility. A ratio greater than one indicates a feasible project.

Benefits and costs are based on the installation of a 300 kW Mini-Hydel station. As indicated in the section on project benefits, the only benefit credited the redevelopment of the Shoal Creek site is the sale of energy under TVA's dispersed power production program. Project costs, which are also detailed in a separate section, include construction costs, debt service, and annual operation and maintenance expenses.

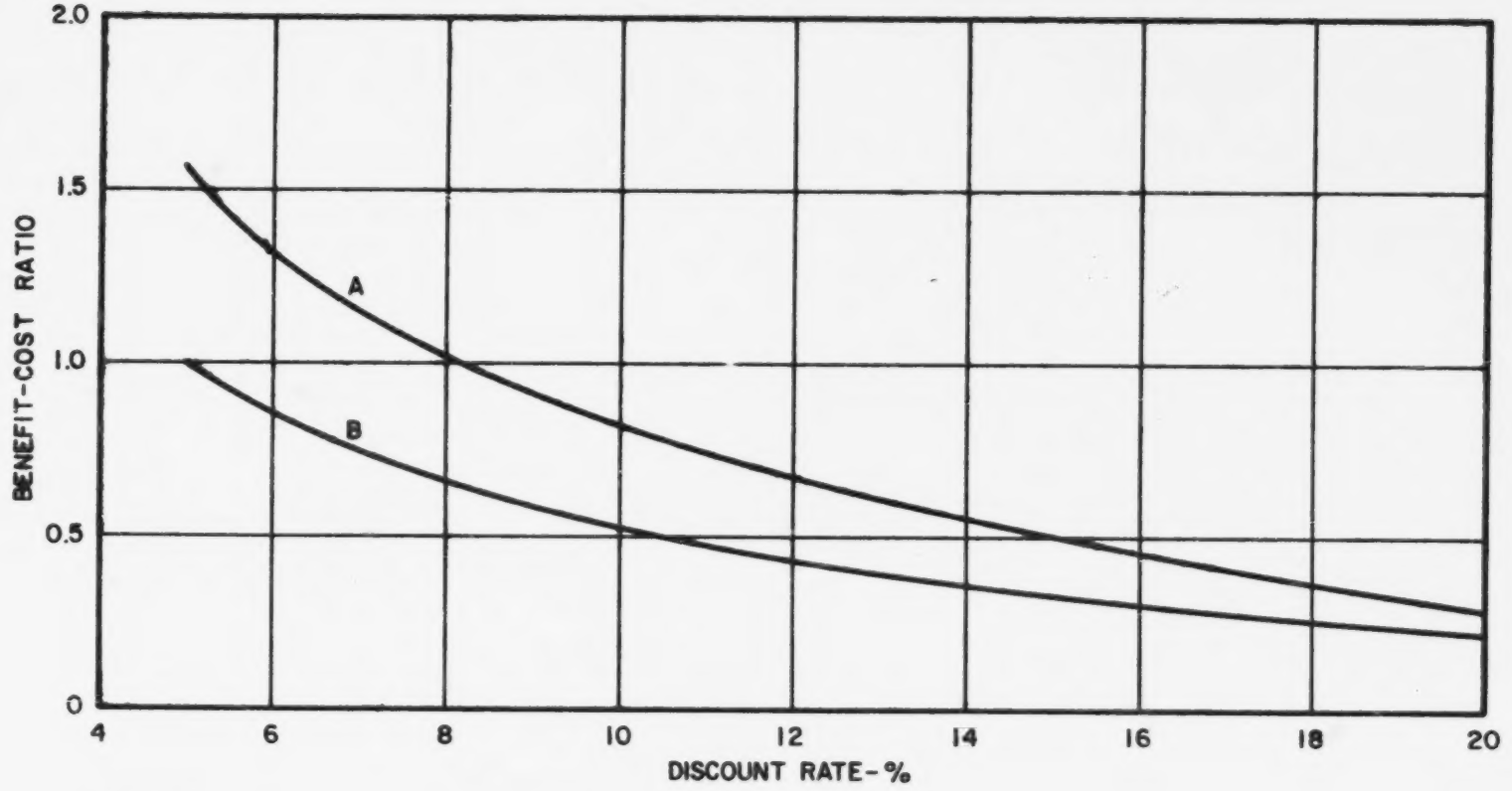
The economic value of project costs and benefits depends on the discount rate, the escalation rate, and the economic life. The discount rate is analogous to the interest paid to borrow money. The escalation rate allows the inclusion of increases due to inflation of the value or cost of future cash streams. The economic life is the period spanning the useful life of the project or the length of the planning horizon.

Figure 7 shows the sensitivity of the benefit-cost ratio to varying discount, escalation, and forecast rates assuming a fixed economic life of 35 years. Assuming a discount rate of 10 percent and the high forecast for benefit escalation, the present worth of the project benefits and costs equals $1,240,000 and $1,511,000, respectively, resulting in a Benefit/Cost ratio of 0.82. It should be recognized that this analysis possibly might not apply to the potential developer. The B/C ratio can be significantly affected by a different prediction of the future state of the economy, a different applicable discount rate, and reduction in the total project cost.

IX. ENVIRONMENTAL ASSESSMENT

Since redevelopment of the Shoal Creek No. 1 site would entail only minor long term changes in the local environment, the environmental consequences of redevelopment are not expected to be significant. This conclusion is consistent with the findings of numerous studies of the impacts of small hydroelectric developments at existing dams whether they have formerly had power producing facilities or not. One such study was done by a consultant for assisting the Federal Energy Regulatory Commission (FERC) in proposing regulations to exempt certain projects from licensing as provided in Part I of the Federal Power Act. To qualify for such exemption, a candidate must be an existing dam, have a total installed capacity of less than 5 MW, and meet the following conditions:

1. Repair or reconstruction of the dam must not raise the normal maximum surface elevation of the impoundment.
2. There must not be significant existing upstream or downstream passage of fish.



LEGEND:
A-High escalation rate for benefits and O&M costs
B-Low escalation rate for benefits and O&M costs

Figure 7. Discount Rate vs Benefit-Cost Ratio

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3. Operation of the dam for hydropower purposes must not change the normal storage and release pattern of the impoundment.
4. The discharge from the powerhouse must be located no more than 300 feet from the toe of the dam.
5. The project must not involve construction at or alteration of a historic site.
6. If the project requires a new transmission line it must be 69 kV or less, and the line must be shorter than one mile if located on a new right-of-way.
7. The project must not adversely affect a federally-designated critical habitat or a federally-designated threatened or endangered species.
8. The project must not cause violations of applicable state or federal water quality standards.

The redevelopment of the Shoal Creek No. 1 site meets all of the above conditions except the requirement that the powerhouse discharge be located a maximum of 300 feet downstream of the dam. This provision ensures that long stretches of channel will not be dried up without proper assessment. However, the bend of Shoal Creek between the dam and powerhouse is presently dry during low flows because of the diversion of Shoal Creek through the tunnel so operation of the site for power production would not drastically alter the flow regime. During construction there would be some adverse environmental impacts such as noise and increased turbidity but these impacts would be temporary.

In sum, neither the assessment of the environmental impacts of redevelopment nor the impacts themselves are expected to be a serious constraint on the redevelopment of the Shoal Creek No. 1 site.

X. CONCLUSIONS AND RECOMMENDATIONS

As indicated in the economic evaluation, the benefit-cost ratio assuming reasonable discount and escalation rates is 0.82. While the benefit-cost ratio exceeds unity for some combinations of discount and escalation rates as shown in Figure 7, even these scenarios are not attractive because of long periods of negative cash flow until the escalating annual benefits exceed the annual cost of debt service and operation.

The economics of the Shoal Creek No. 1 site are unattractive for several reasons. First is the generally poor condition of the existing facilities which would require approximately one-third of the total capital investment to repair. Second is the small capacity and low energy production dictated by the site and flow regime. Equipment and operating costs do not decrease linearly with capacity so the energy produced at small plants becomes relatively expensive. Finally, the value of energy benefits in the TVA area is less than in most other parts of the country due to TVA's comparatively lower electric power rates.

Aside from the unfavorable economics of the Shoal Creek No. 1 site, there are uncertainties pertinent to the decision to redevelop which have not been completely addressed. For example, preliminary analysis of the dam using current design standards indicates the possibility of dam failure during high flows. While failure would probably not pose a safety hazard, it would render the capital investment of redevelopment useless since the cost of dam replacement would be prohibitive.

Because of the low rate of return on investment and the uncertainty of this return, it is recommended that further consideration for the redevelopment of the Shoal Creek No. 1 site be delayed until a significant change occurs in the conditions that impact the economics.

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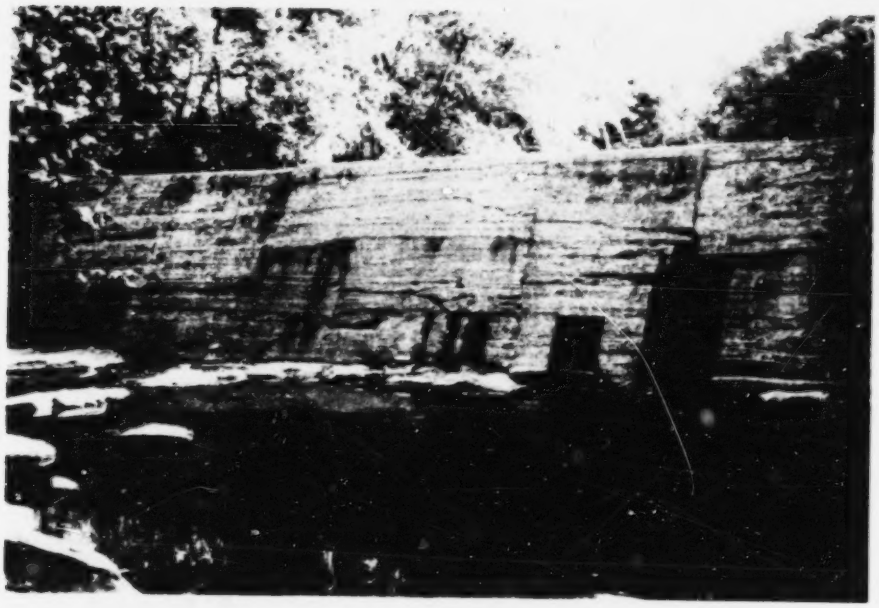
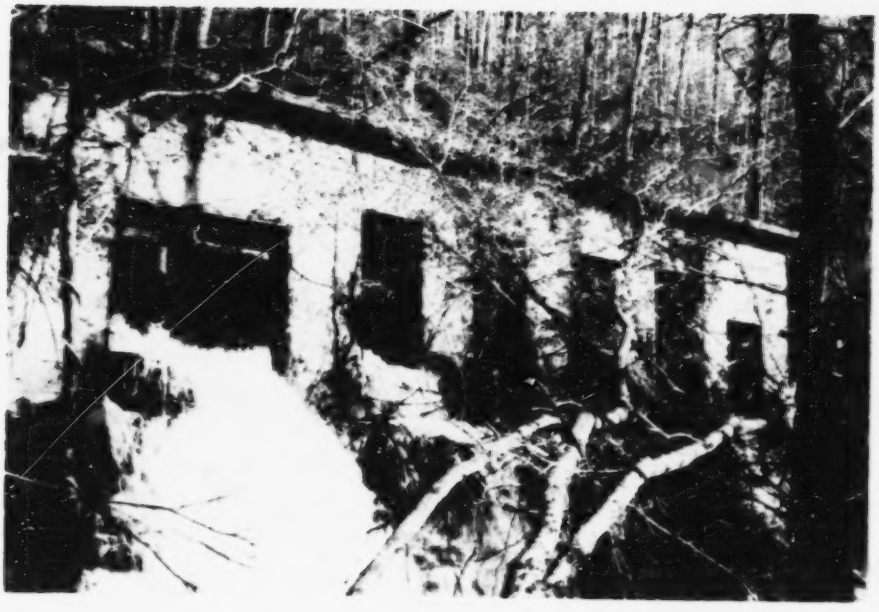


Downstream view of dam



Downstream view of powerhouse

APPENDIX I

SPARTA DAM

APPENDIX I

FEASIBILITY REPORT - SPARTA DAM

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SUMMARY OF PRINCIPAL FEATURES

Sparta Dam

Location
On the Calfkiller River approximately 1.2 miles southwest of Sparta, in White County, Tennessee.

Owner
Joe Snodgrass

Streamflow	
Drainage area	175 sq. miles
Average discharge	370 cfs
Tailwater	
Normal operating	El. 817.3
Minimum	El. 816.0
Operating Heads (net)	
Maximum	22.7 ft
Minimum	6.6 ft
Rated	19.7 ft
Dam	
Type	concrete gravity
Length	430 ft
Height	7 ft
Top of spillway	El. 839.0
Possible Power Facilities	
Type	prefabricated hydroelectric generating station
Hydraulic turbines	
Number	one
Type	Francis, vertical shaft
Runner diameter	1450 mm (57 in)
Generator	
Type	induction
Rating	300 kW
Plant output:	
Average annual energy	1,400,000 kWh
Existing intake structure	reinforced concrete with four 4.5 ft x 5.0 ft openings
Existing flume	1000 ft concrete channel
Existing forebay	15 ft x 55 ft reinforced concrete
Cost	
Total project cost	$620,000
Cost per kW	$2,100

SUMMARY

This report presents the results of a study to determine the feasibility of restoring the hydroelectric generating facilities at Sparta Dam. The costs used for this report reflect construction costs experienced by TVA including overheads normally used in TVA accounting procedures and may or may not apply to a developer.

The analysis using TVA costs and benefits and an assumed discount rate indicates that the redevelopment of Sparta Dam is marginal. The project could prove economically feasible to a developer who could reduce costs, obtain financing at a lower discount rate, and take advantage of tax incentives available to small hydro investors.

I. INTRODUCTION

The purpose of this report is to investigate the possibility of restoring hydroelectric power generation facilities at the Sparta Dam on the Calfkiller River in White County, Tennessee.

This report is part of the second phase of TVA's Small Hydro Program which was begun in 1979 to investigate the potential for small scale hydroelectric production in the Tennessee Valley region. The first phase, which was completed in June 1980, consists of an inventory and screening of existing non-Federal dams in the Tennessee Valley and the TVA power service area. The second phase consists of more detailed feasibility studies on ten of the most promising sites based on the results of the reconnaissance phase.

Included in the feasibility analysis for Sparta Dam is a detailed cost estimate, evaluation of project benefits, and computation of a Benefit-Cost ratio. A potential developer can use these to help make a decision regarding whether or not to proceed with rehabilitation of the facility.

II. SITE HISTORY

Early in this century J. T. Anderson, J. R. Tubb, O. H. Anderson, and S. B. Anderson formed the Anderson and Tubb Power Company and constructed the Sparta station in 1909 to deliver electric power to nearby Sparta. In 1917 the Tennessee Electric Power Company purchased the plant and operated it regularly until the early 1930's when the plant was placed on standby service. During the period 1925-31, the plant output averaged 730,000 kWh annually at a production cost of approximately 2.5 mills/kWh.

The Sparta project was among the assets of the Tennessee Electric Power Company acquired when that company was purchased by TVA in 1939. At that time the plant was not in operable condition, but all equipment was still intact. In 1939, the cost of electricity which would be produced by the Sparta station if it were restored to service was estimated to exceed the displaced fuel cost of the system's steam plants. Because of its high operating costs and small capacity, the project was never operated by TVA and was finally sold in March 1941 to Mr. R. J. Snodgrass, the father of the present owner, Mr. Joe Snodgrass.

Following the sale of the project to private owners most of the equipment was removed for its salvage value. The project has been abandoned now for forty years and all the existing structures are in a dilapidated condition having received no maintenance at all. The approximately 140 acres comprising the site are presently used for agricultural purposes.

III. SITE DESCRIPTION

A. General

The Sparta project is an old hydroelectric facility located on the Calfkiller River in White County, Tennessee, about 1.2 miles southwest of the county seat of Sparta (see Figures 1 and 2). Access to the site is by State Highway 111 which crosses the river immediately below the dam. The original access roads to the flume and powerhouse are in very poor condition.

The three major elements of the existing project are the dam, flume and powerhouse (see Figure 3). In the past, water was diverted by

Figure I. Location Map

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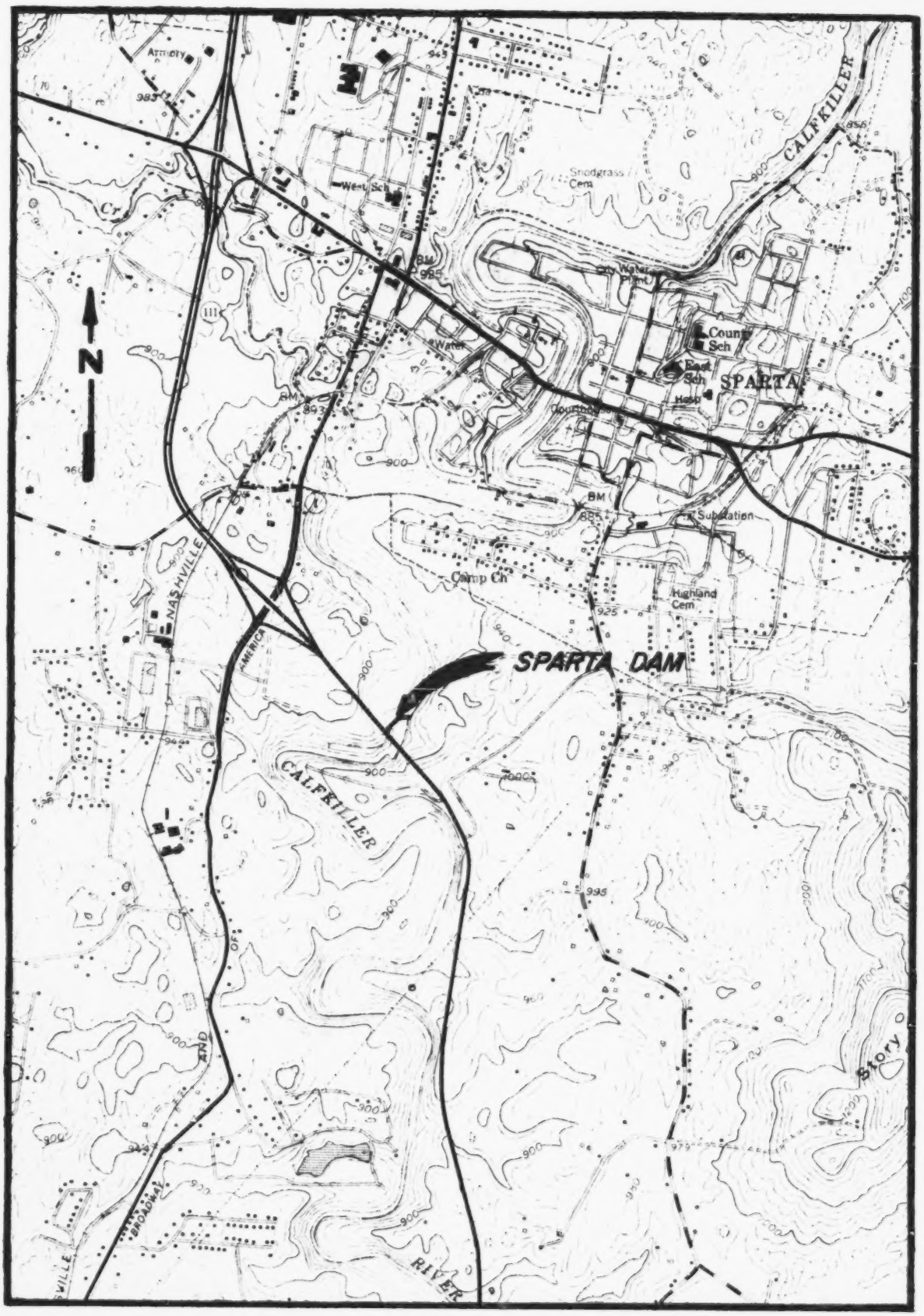

Figure 2. Vicinity Map

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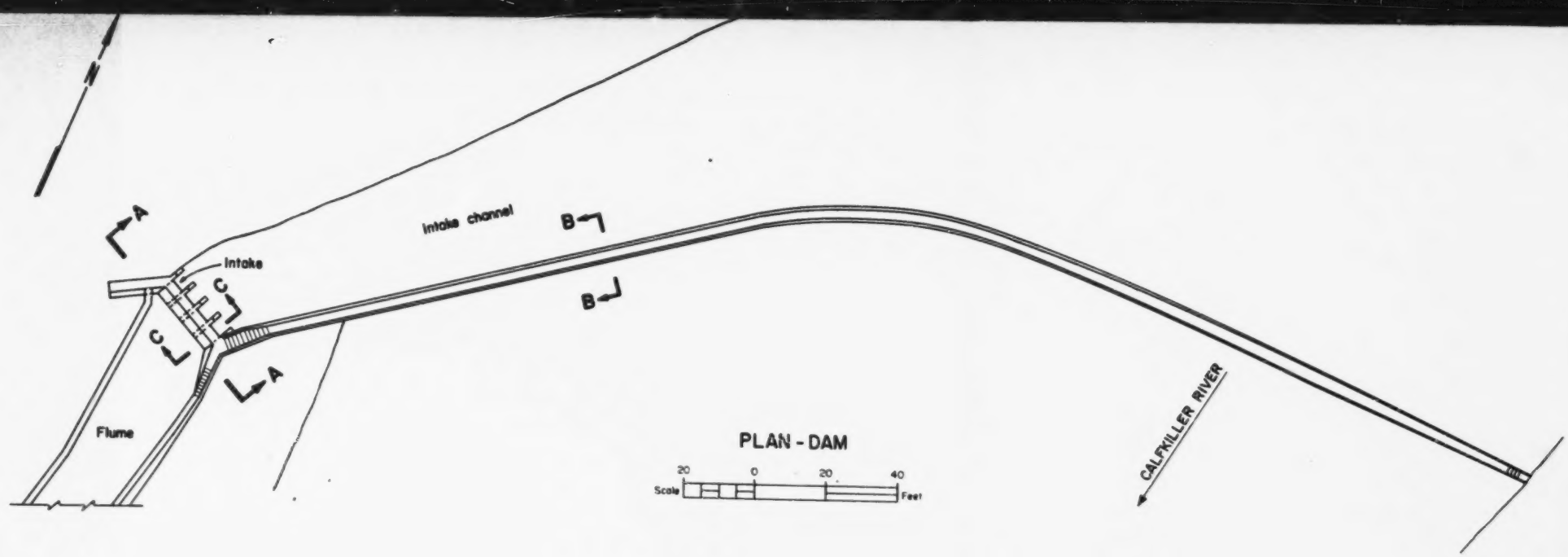

PLAN - DAM

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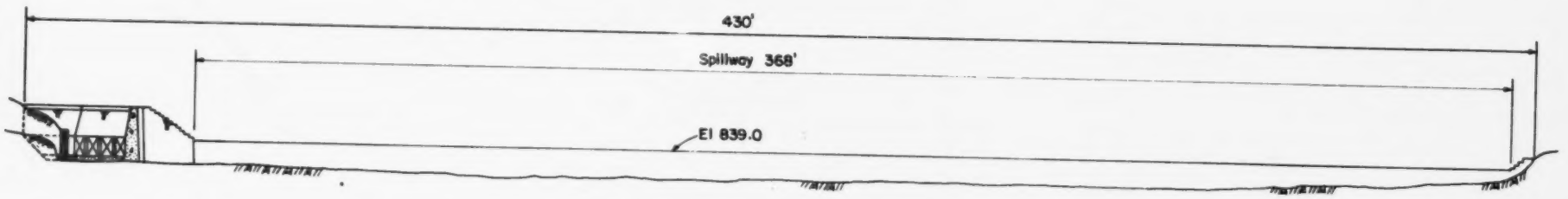
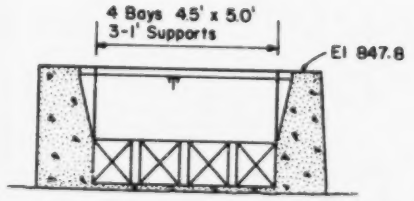


DOWNSTREAM - ELEVATION - DAM

Not To Scale



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SECTION B-B

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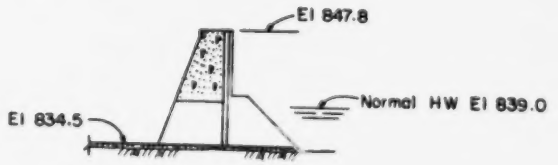

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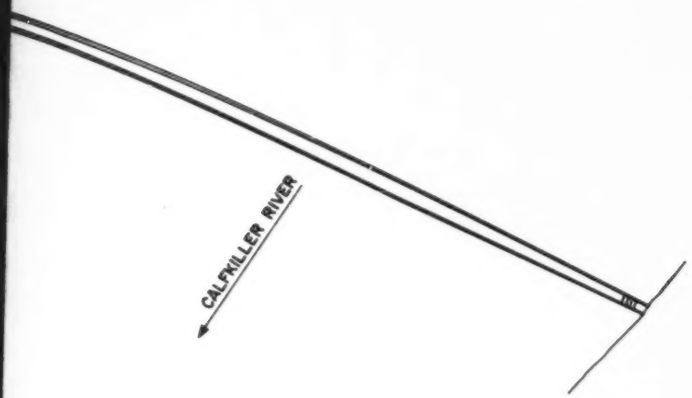

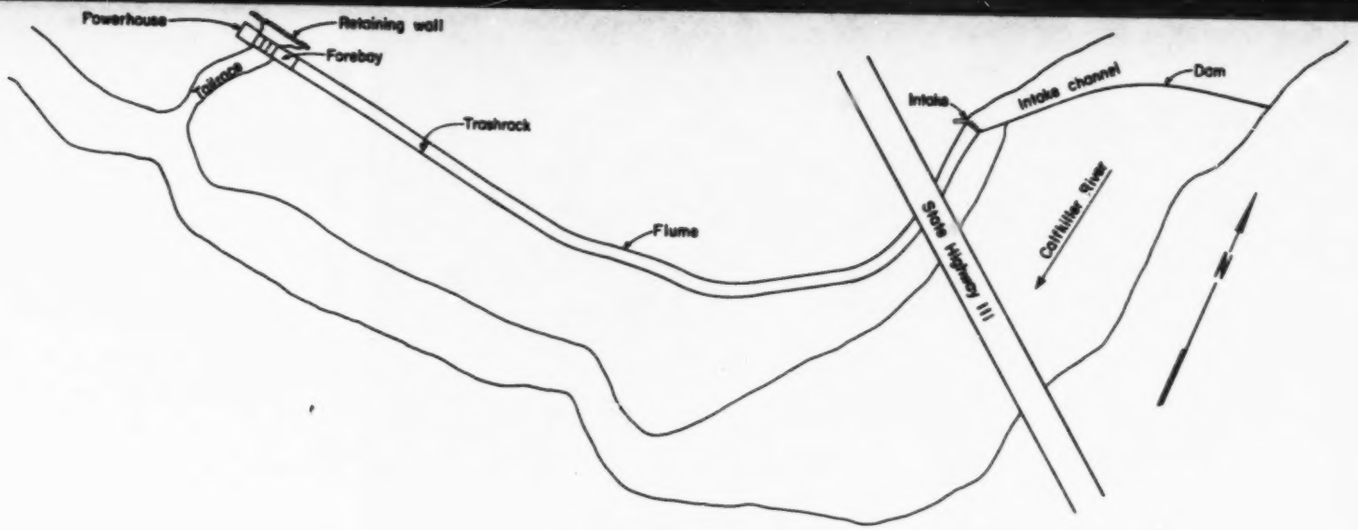

SITE PLAN

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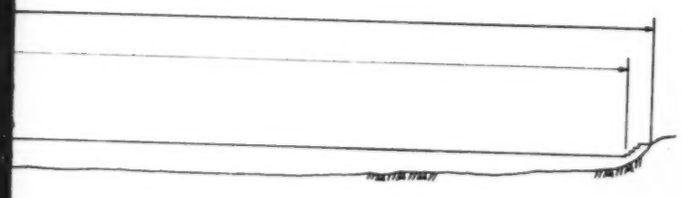

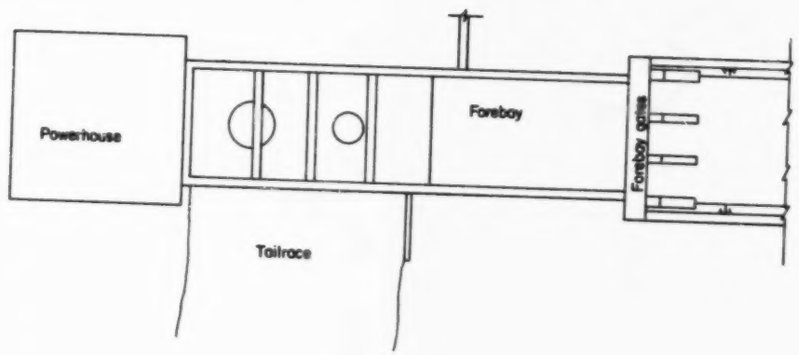

PLAN - POWERHOUSE AND FOREBAY

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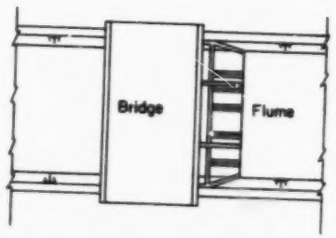

PLAN - TRASHRACK

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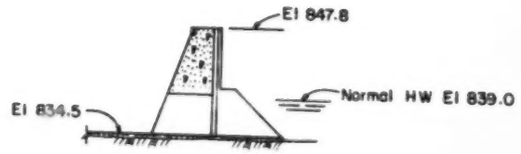

SECTION C-C

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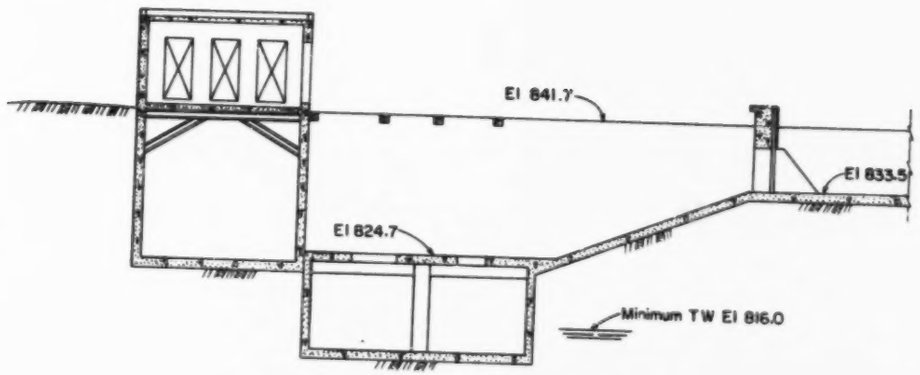

SECTION THRU POWERHOUSE AND FOREBAY

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Figure 3. Existing Facilities - Sparta Dam

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the dam from the river into the flume which carried the water on a nearly level grade approximately 1000 feet down the right bank of the Calfkiller River to the powerhouse. Here the flume terminated in an open forebay containing a horizontal double runner turbine. After passing through the turbine, the water was discharged into an earthen tailrace channel approximately 150 feet long which led back to the river.

B. Dam

The diversion dam is a trapezoidal concrete gravity structure extending 400 feet in an arc from the left bank to the intake structure on the right bank so as to form an entrance channel. The height varies from five to seven feet. The structure is in sound condition and would not require major repairs. The foundation is limestone characterized by many bedding planes and broken slabs. At two points, about 40 feet and 50 feet from the left abutment, there are leaks under the dam which total about 50 cfs when the headwater is at the top of the dam. The reservoir has negligible storage and is heavily silted.

C. Flume

The flume intake is a concrete structure with provision for four headgates and operating equipment to admit water to the flume. The 17 foot wide flume is rock and concrete lined for the first 500 feet and concrete lined for the remaining 500 feet. Portions of the concrete lining in the upper section are damaged and would have to be repaired if returned to service. The intake and flume are filled with silt and choked with heavy undergrowth and fallen trees.

D. Forebay

The forebay consists of a gated structure opening into a 17 foot deep concrete enclosure containing a horizontal turbine in an open flume setting. No signs of major structural distress are evident in the forebay. The double runner horizontal turbine which was installed in 1924 to replace the original triple runner turbine is still in place but is in extremely poor condition having been dewatered and exposed to the elements for over 40 years. This unit was rated at 300 horsepower under a 23 foot head.

E. Powerhouse

The powerhouse is a small concrete structure located at the end of the forebay which housed the generator, governor, and station equipment. It is structurally sound but has been stripped of all equipment, doors, windows, and other fixtures.

F. Tailrace

The tailrace channel from the powerhouse to the river is heavily silted, particularly at the outlet where the river has formed a sand bar.

IV. HYDROLOGY AND HYDRAULICS

The Calfkiller River at the site of the Sparta plant drains a 175 square mile watershed devoted primarily to agricultural use. Annual precipitation in the area is about 54 inches. Based on USGS records available for the Calfkiller River, the average flow at the site is 370 cfs and the seven day, ten year low flow is 17 cfs.

Figure 4 is the duration of flow curve developed for the Calfkiller River based on streamflow records from the USGS stream gage approximately 4000 feet below the dam. The period of record is from 1941 to 1971. Since the drainage area at the dam is only three square miles less than at the gage, the flows are unadjusted.

Because of the low hazard potential of the Sparta Dam, the 100 year flood has been selected as the design flood for this study. Based on flood studies done at Sparta, the 100 year flood on the Calfkiller River is approximately 21,000 cfs. During high flows the dam is completely submerged, and there is little difference between the headwater and tailwater elevations. Failure of Sparta Dam would pose no downstream hazard.

V. PROJECT DEVELOPMENT

The procedure to determine the most cost-effective scheme for redevelopment of the Sparta plant consists of studying various alternatives and comparing the costs to the energy benefits.

Much of the work required for redevelopment is common to all alternatives. This work includes stopping of foundation leaks, repairs to the flume, providing new intake and forebay gates, installing trashracks, access road repair, tailrace excavation, general yard work, and construction of transmission facilities.

The Sparta flume is limited to a maximum flow of approximately 250 cfs which is two-thirds of the average flow of the Calfkiller River. Some consideration was given to the possibility of increasing the capacity of the flume, but it was determined that the costs would be prohibitive. Alternative power installations were, therefore, limited to the use of the existing flume.

Two major schemes were considered using the existing flume. One alternative was to use the existing powerhouse in conjunction with a vertical Francis turbine and right angle speed increaser connected to a horizontal generator located in the powerhouse. However, the most feasible arrangement was determined to be the prefabricated Mini-Hydel hydroelectric generating station.

The Mini-Hydel station is manufactured by Barber Hydraulic Turbine, Ltd. and is completely assembled and tested prior to delivery. It features a turbine with a standard Francis runner and a generator which is in a waterproof steel housing directly above the turbine. As shown in Figure 5, the station would be mounted in an open flume setting using the existing draft tube opening in the forebay. Normal operation would be unmanned with manual startup and automatic shutdown. Use of an induction generator, which would take its frequency and voltage regulation from the power grid, would eliminate many of the problems of interfacing a small generator with a large system. A hydraulic gate operator and reservoir level monitor would prevent drawing of the reservoir during low flows.

Based on power studies, a unit with a 1450 mm (57 in) diameter turbine runner has been selected. This unit would provide approximately 300 kW at a rated net head of 19.7 feet. The details of the power production and costs of this installation are described in separate sections.

VI. POWER PRODUCTION

It is assumed that operation of the possible hydroplant would be run-of-river. The potential power was determined utilizing the duration of

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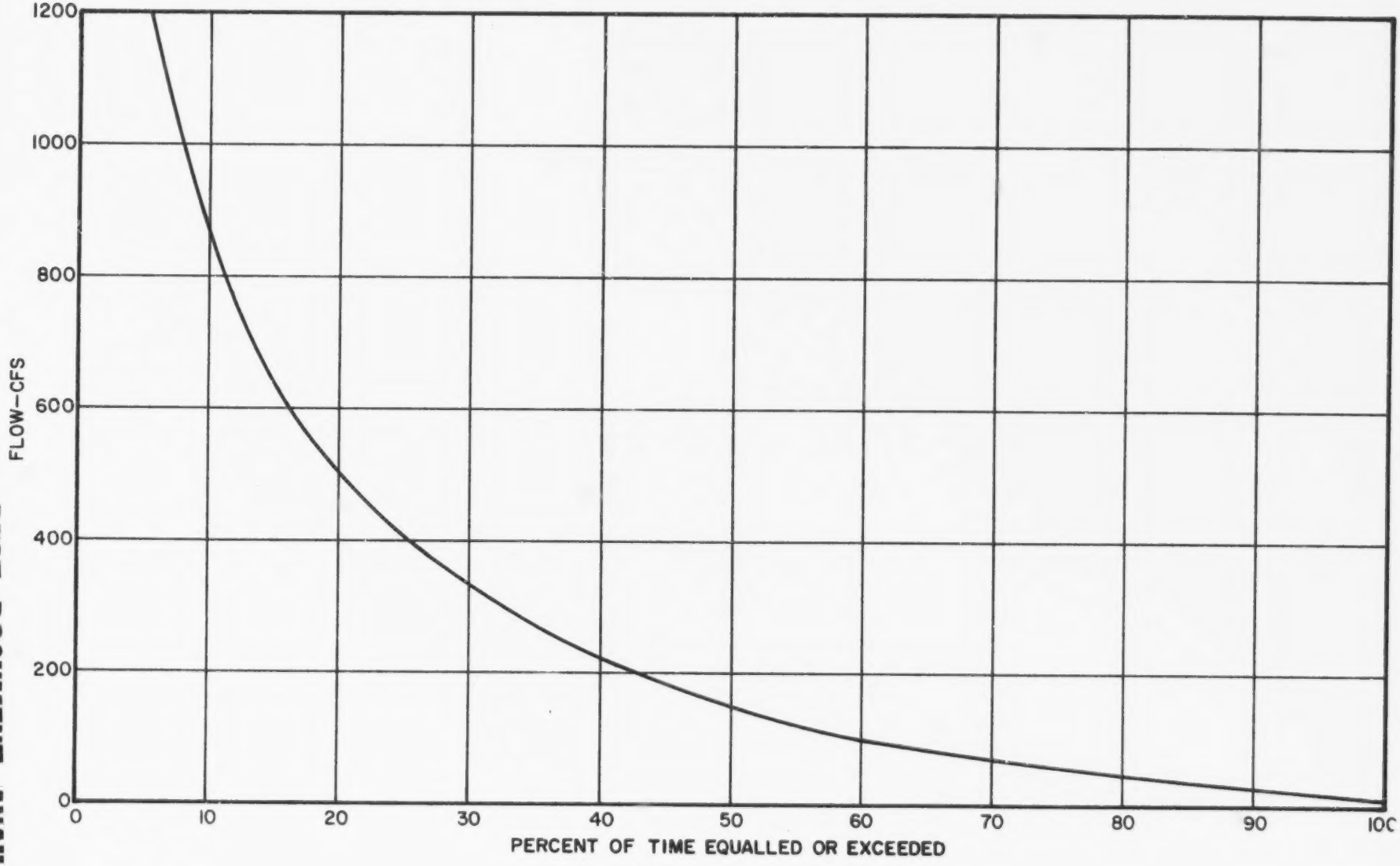

Figure 4. Duration of Flow

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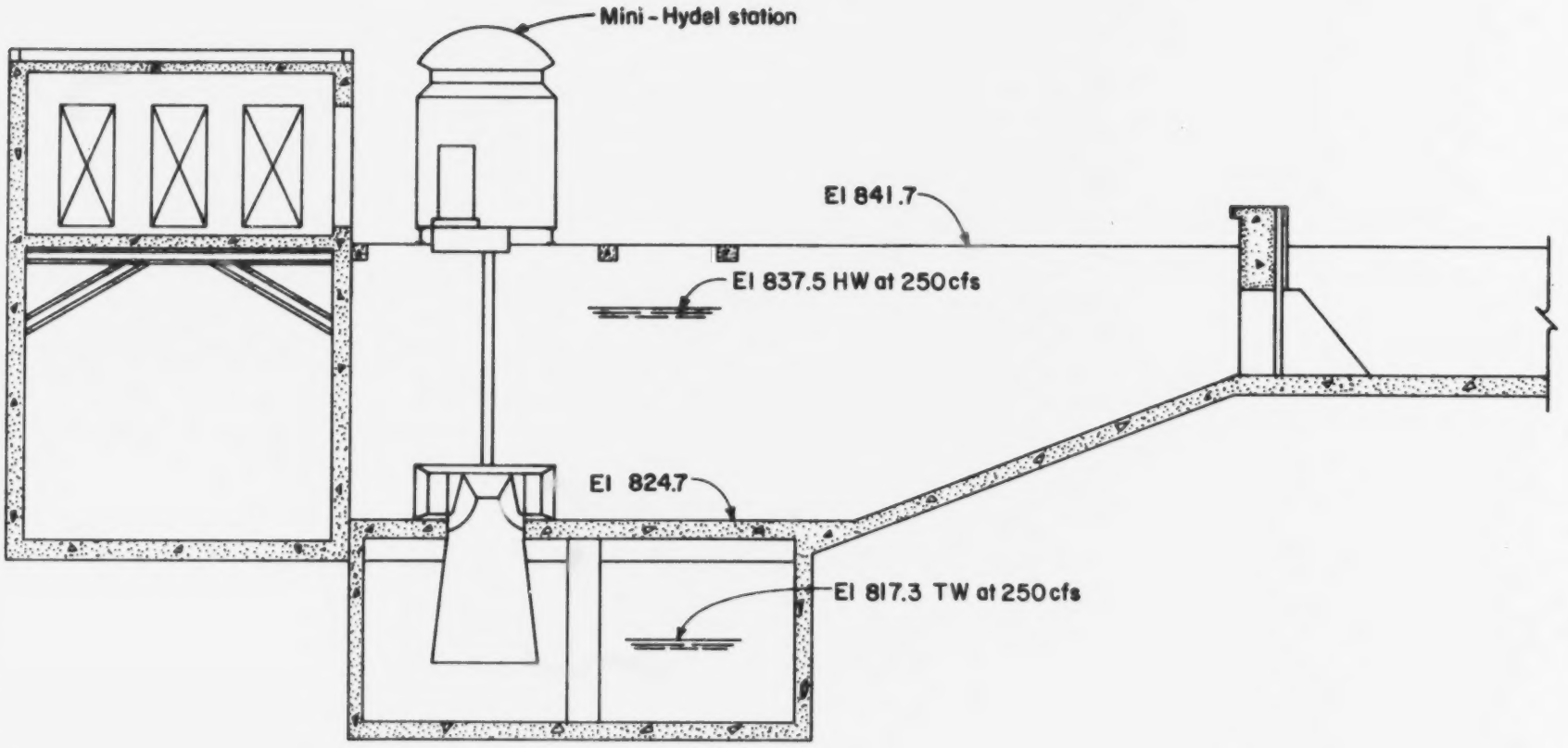

SECTION THRU FOREBAY
Scale 1"=10'

Figure 5. Possible Redevelopment Plan - Sparta Dam

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flow curve shown in Figure 4. Usable flow under the curve was divided into several increments and average annual generation was computed by summing the potential energy from each increment under the curve. For this computation, a specific efficiency value was assigned to each increment of flow based on manufacturer's unit performance curves, and net heads were computed using a tailwater curve and accounting for losses in the system.

Average annual energy produced by the Mini-Hydel station was estimated to be 1,400,000 kWh. At full gate (250 cfs) the unit is rated at 300 kW with an overall efficiency of 72 percent at 19.7 ft net head. For approximately 40 percent of the time, flow conditions would not be suitable for plant operation.

VII. PROJECT COSTS

The project cost in 1981 dollars of the most feasible redevelopment plan is $620,000 and is comprised of estimates of equipment and structural costs, interest during construction, contingencies, and overheads. The major items in the estimate are repair of the existing facilities, site preparation, and mechanical and electrical equipment. A summary of these costs is shown in Figure 6. The manufacturer supplied the cost of the prefabricated station and other costs are based on TVA's estimated costs. Operation and maintenance expenses are assumed to be $10,000 per year in 1981 dollars.

It should be recognized that these costs are based on TVA's experience on similar work at larger projects and may not be applicable to all developers. There could be some cost savings if a developer could

acquire suitable used equipment and if he could provide labor and materials at a lower cost.

VIII. PROJECT BENEFITS

Benefits from the possible hydro facility are based on the amount of energy made available to the local transmission system. The Public Utility Regulatory Policies Act of 1978 (PURPA) requires a utility to purchase energy offered for sale by a qualifying facility. The value of this energy is determined using the rates adopted by TVA under its Dispersed Power Production Policy. Under the program's present rate structure for plants having 100 kW or greater capacity, the price for on-peak electricity is 4.489 cents per kWh and 2.826 cents per kWh for off-peak electricity. Since plant operation at Sparta Dam would use the available inflow without regard to the time of day, the weighted average of these two rates, 3.407 cents per kWh, has been used to evaluate the energy production. Using this value, the potential average annual generation of 1,400,000 kWh at Sparta Dam is worth approximately $47,700. The energy value is subject to change in accordance with the adjustment provisions of TVA's wholesale power contracts.

IX. ECONOMIC ANALYSIS

The feasibility of restoring the hydro facilities at Sparta Dam was evaluated by comparing the present worth of the project's benefits and costs over an assumed 35-year economic life of the project to form a Benefit-Cost (B/C) ratio. Benefits are based entirely on the amount of

SPARTA DAM

HYDROELECTRIC PLANT REHABILITATION

Estimate of Cost[1]

General Yard Improvements	$ 28,000
Powerhouse	20,000
Reservoir	15,000
Concrete Dam	24,000
Intake	10,000
Water Conductors	21,000
Turbine - Generator and Electrical Equipment	250,000
Construction Facilities	46,000
Total Direct Construction	414,000
Field General Expense	29,000
Contingency	56,000
Total Field Construction	499,000
Interest During Construction	35,000
Total Construction	534,000
Engineering Design	62,000
Administration	24,000
Total Project	$620,000

[1]Total project cost is based on 1981 dollars. This estimate does not include the primary reclosure or the 13.2 kV to 480 V transformer.

Figure 6: Cost Estimate

energy supplied to the local transmission system. Project costs are comprised of the capital cost of the rehabilitation work and the present worth of operation and maintenance costs. A discount rate of 15 percent, which is the approximate current prime rate, was assumed since the most likely developer would be a private investor.

The present worth of power benefits and operation and maintenance costs was computed for two different economic forecasts. An escalation rate of 10.5 percent was assumed for the first eleven years in the high forecast and 10.0 percent for the remainder of the economic life. In the low forecast 7.3 percent escalation was assumed for the first 11 years, 5.5 percent for the next 8 years, and 6.0 percent for the last 16 years.

The present worth of the project benefits and costs for the high forecast equals $778,000 and $783,000, respectively, resulting in a B/C ratio of 0.99. The low forecast present worth values for project benefits and costs are $535,000 and $732,000, respectively, which yield a B/C ratio of 0.73. Based on these values the project appears marginally feasible at best. However, it is emphasized again that the assumptions made in this analysis do not necessarily apply to each developer.

Figure 7 shows the sensitivity of the B/C ratio to varying discount and escalation rates assuming a 35-year economic life. The B/C ratio can be significantly affected by a different prediction of the future state of the economy, a different applicable discount rate, and reduction in the total project cost.

X. ENVIRONMENTAL ASSESSMENT

The environmental effects of hydro projects, which have relatively small existing dams and operate as run-of-river plants, are most often

minimal. This concept is consistent with independent studies made by several organizations. One such study was done by a consultant for assisting the Federal Energy Regulatory Commission (FERC) in proposing regulations to exempt certain projects from licensing as provided in Part I of the Federal Power Act. To qualify for such exemption, a candidate must be an existing dam, have a total installed capacity of less than 5 MW, and meet the following conditions:

1. Repair or reconstruction of the dam must not raise the normal maximum surface elevation of the impoundment.
2. There must not be significant existing upstream or downstream passage of fish.
3. Operation of the dam for hydropower purposes must not change the normal storage and release pattern of the impoundment.
4. The discharge from the powerhouse must be located no more than 300 feet from the toe of the dam.
5. The project must not involve construction at or alteration of a historic site.
6. If the project requires a new transmission line, it must be 69 kV or less, and the line must be shorter than one mile if located on a new right-of-way.
7. The project must not adversely affect a Federally-designated critical habitat or a Federally-designated threatened or endangered species.
8. The project must not cause violations of applicable State or Federal water quality standards.

The possible redevelopment of the Sparta Dam project meets all of the above conditions except (4). Discharge from the powerhouse would

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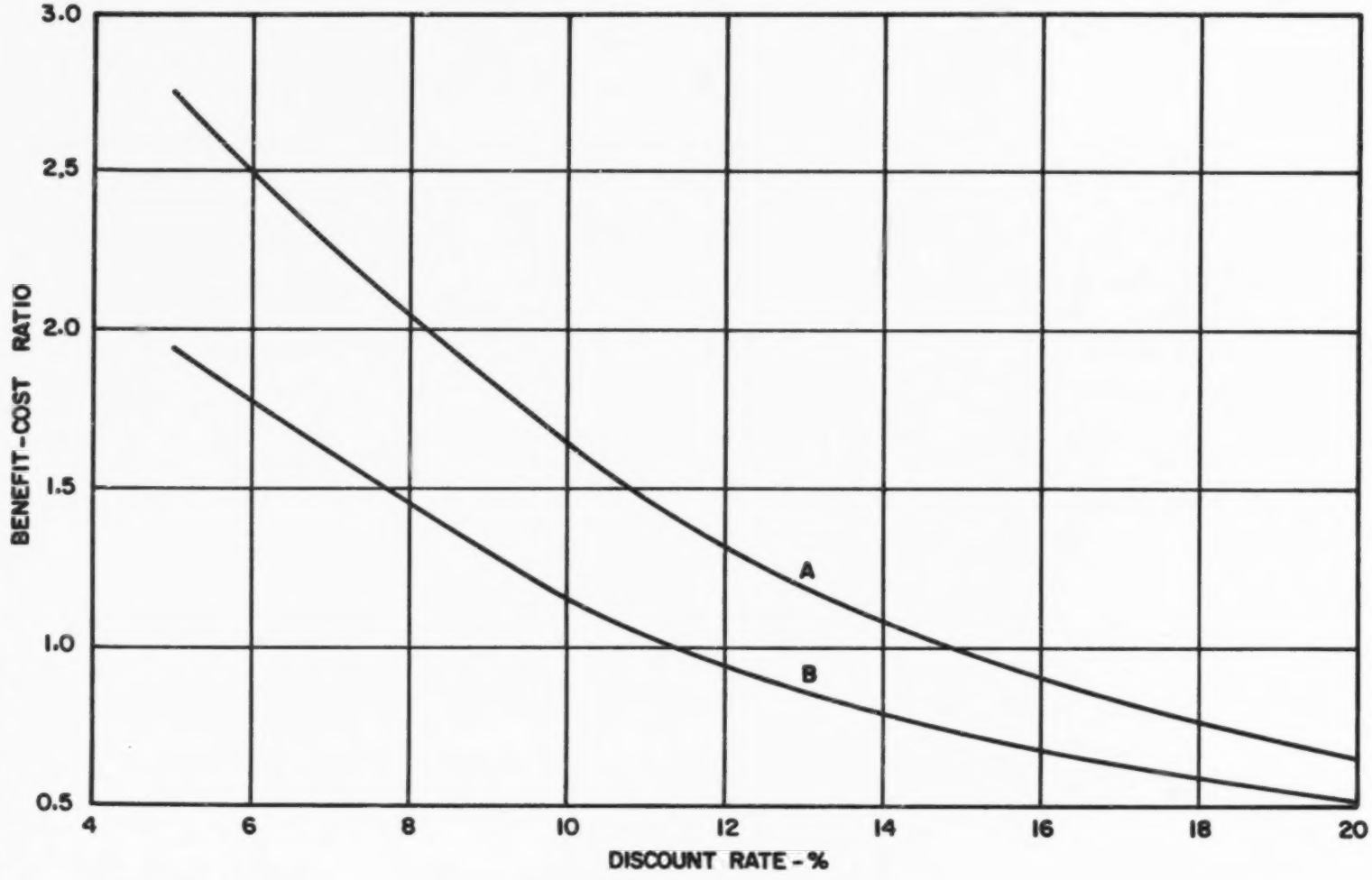


LEGEND: A - High escalation rate for benefits and O&M costs
B - Low escalation rate for benefits and O&M costs

Figure 7. Discount Rate vs Benefit-Cost Ratio

reenter the river approximately 1,500 feet downstream of the dam, causing this stretch of river to have little or no flow approximately 25 percent of the time.

It is not anticipated at this level of study that such a reduction in flow would cause a serious impact on the environment. Most importantly, there are no special fish or wildlife populations which would be disturbed by operation of the plant. Also, there is no sewage discharge into this stretch of river which would affect water quality.

The developer should be aware that a minimum flow may be required if further study reveals that drying up the channel would cause a serious environmental impact or if future legislation establishes this requirement. The provision of a minimum flow would reduce the average annual generation of the plant.

However, it is expected that long term environmental effects would not be a significant deterrent to the rehabilitation of the project. Short term effects caused by construction, such as an increase in the turbidity of the water and construction noise, would be minimized by proper construction techniques and would be only temporary.

XI. CONCLUSIONS AND RECOMMENDATIONS

Based on the analysis made in this study, the feasibility of restoring the hydroelectric generating facilities at Sparta Dam would be marginal at best. Depending upon the economic forecast assumed, the Benefit-Cost ratio ranges between 0.73 and 0.99 at a 15 percent discount rate.

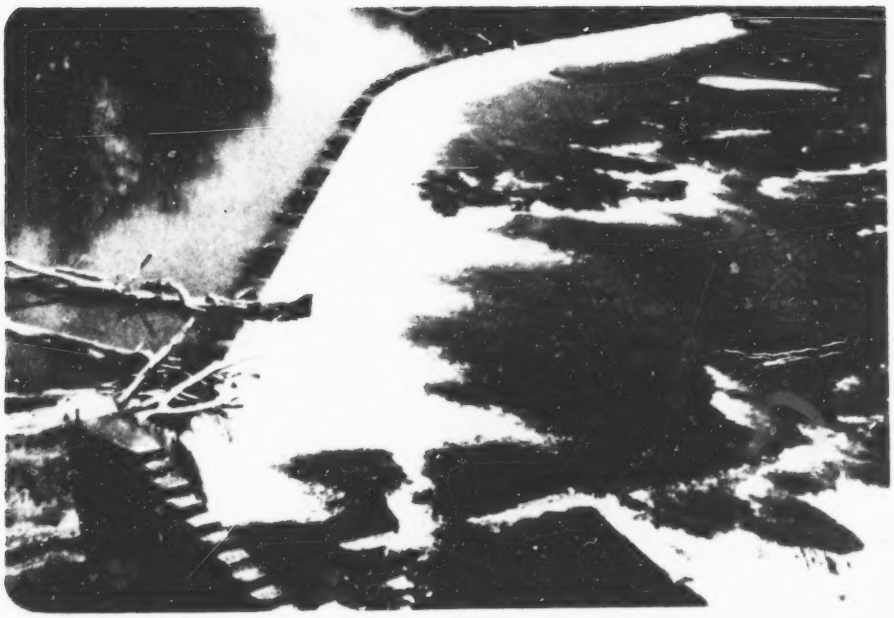
As mentioned in previous sections, assumptions made in this analysis may or may not apply to a potential developer. Favorable economics would depend on a developer's ability to reduce costs, his ability to secure low interest financing, and his financial situation being such that he could take advantage of tax benefits available to small hydro investors. The total project cost is based on TVA costs and accounting procedures, and could be reduced if a developer could obtain suitable used equipment, provide labor, materials, and operation and maintenance expenses at a lower cost, and reduce overhead costs. A developer may also be able to utilize the existing turbine by restoring it to good operating condition.

There are also some disadvantages to be considered. For the first several years of operation there could be negative cash flows until escalating benefits reach and surpass costs. In addition, environmental impacts from drying up 1,500 feet of river channel could complicate the project by requiring further study of these impacts and possibly the provision of a minimum flow. Should a minimum flow be required at the site, the average annual energy production of the plant and thus the benefits of the project would be reduced.

Several regulations apply to small hydro projects and must be complied with. A developer should be prepared to obtain the required licenses and permits to construct and operate the project from the appropriate organizations on the local, State, and Federal levels of government. Some agencies which do not require a permit or license must be contacted for comment on the project.

An investor interested in developing this site in light of the above problems and requirements should make an analysis based on his

individual financial situation to determine whether or not to proceed with redevelopment.



View of dam.

View of powerhouse.

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